Energy, Mines and Resources Canada

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CANMET

Canada Centre for Mineral and Energy Technology

Centre canadien de la technologie des minéraux et de l'énergie

Coal Research Laboratories

Laboratoires de recherche sur le charbon

Canada

91-02583/

SEAFLOOR TOPOGRAPHY OVER THE PHALEN COLLIERY, PHASE 3 - 1989 SYDNEY COALFIELD CAPE BRETON, NOVA SCOTIA

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EXECUTIVE SUMMARY

A 59 km grid of marine high resolution echosounder data was acquired over the Phalen Colliery on behalf of the Canada Centre for Mineral and Energy Technology (CANMET), Cape Breton Coal Research Laboratory. The survey was conducted in September 1989, providing the third year of a multi-year study designed to evaluate mining induced seafloor subsidence through comparison of the pre-mining and post-mining seafloor profiles.

Bathymetric profiles collected along the 1989 survey lines were digitized, and combined with the corresponding navigation data, to produce displays of the seafloor profiles and survey line plans above the Phalen longwalls. These profile and plan displays were created and stored as Autocad drawing files, allowing for direct superposition with the corresponding 1987 and 1988 displays.

Longwall excavation during the period intervening the 1988 to 1989 surveys, resulted in 8 pre-mining/post-mining seafloor profiles. An examination of these profiles in the proximity of longwall mining revealed previously unobserved subsidence, along lines 2 (West Phalen No. 1), 15 and 16 (East Phalen No. 1). Between 0.2 and 0.8 metres of vertical displacement was measured above these longwalls. The seafloor along the 5 additional profiles (line 1, West Phalen No. 1 and lines 13, 19, 20 and 21, East Phalen No. 2) did not positively reveal subsidence. The absence of measurable subsidence along these lines is probably due to insufficient time between longwall excavation and seafloor profile acquisition.

Subsidence was also recorded along line 3 (West Phalen No. 1). Excavation of this longwall, beneath line 3, was completed immediately prior to the 1988 survey. The amount of subsidence revealed by comparing the 1988 and 1989 profiles along this line was between 0.2 and 0.3 metres vertical displacement.

Comparisons between the remaining 1987 and 1989 profiles failed to demonstrate additional subsidence beyond that reported in the 1988 study (McGregor, 1989). This is interpreted to indicate that the dominant period of subsidence, affecting the seafloor above the Phalen longwalls, is during the first year post-mining.

A remotely operated submersible was used to acquire color video imagery of the seafloor over the Phalen longwalls. This was used to confirm the presence of bedrock exposed at the seafloor and the complex microtopography indicated by the bathymetric records. The presence of exposed bedrock at the seafloor is an important criteria for ensuring that the changes in seafloor topography result from mining and not from sediment transport.

Conclusive evidence of mining induced seafloor subsidence has been found in this study. The magnitude and location of these subsidence observations have been documented in this report. These empirical data

are required to calculate the tensile strain of the rock mass above the Phalen seam and test the validity of current mining guidelines.

SOMMAIRE EXÉCUTIF

Cinquante-neuf (59) kilomètres de données d'écho-sondeur à haute résolution ont été acquises au-dessus du site de la Mine de Houille Phalen dans l'intérêt du Laboratoire de Recherche du Charbon du Cap Breton, du Centre Canadien de la Technologie des Minéraux et de l'Énergie (CANMET). Ce levé a été mené durant le mois de Septembre, 1989. Il constitue la troisieme année d'une étude polyphasé ayant comme but l'évaluation de la subsidence du fond marin induits par les travaux miniers, et ce, par comparaison entre les profiles du fonds marin pre- et post-miniers.

Les profils bathymetrique acquis au long des tracés du levé de 1989 ont été numérisés et combinés avec les données de navigation correspondant, de facon à visualiser les profils du fond marin et les plans des tracs lev au-dessus des longues tailles de Phallen. Chacun de ces profils et illustrations de plan se trouvent sous la forme de fichiers illustrés dans le logiciel AUTOCAD. Ce logiciel permet la superposition des illustrations de 1987 et 1988.

L'extraction minière par longue tailles durant la période du levées de 1988 et 1989 ont permis l'acquisition de 8 profils sous-marin pré- et post-minièr. L'examination des profils qui ont été levé près de la région d'extraction minière par longue tailles revèle une subsidence qui n'a jusqu'à maintenant pas été observé le long des lignes 2 (Ouest Phalen No. 1), 15 et 16 (Est Phalen No. 1) avec déplacement vertical de l'ordre de 0.2 à 0.8 mtres. Aucune subsidence du fond marin n'a été observé de facon certaine le long des cinq profils additionnel (ligne 1 Ouest Phalen No. 1 et lignes 13,19, 20 et 21, Est Phalen No. 2). L'absence d'une subsidence mesurable le long de ces lignes est probablement dû à une trop courte intervalle de temps entre l'extraction minière par longue tailles et l'acquisition des profils sous-marin.

Une subsidence a également été enregistré le long du profil 3 (Ouest Phalen No. 1). L'extraction miniere de cette longue taille, situé sous la ligne 3, a été completé juste avant le levé de 1988. En comparant les profils de 1988 et 1989 un déplacement vertical entre 0.2 et 0.3 mètre est mesuré le long de cette ligne.

Une comparaison des profils de 1987 et 1989 ne montre aucune subsidence additionelle autres que celles rapporté dans le levé de 1988. Cet observation indique que la première année après l'extraction minière represénte la période la plus importante pour la subsidence du fond marin au-dessus des longues tailles Phallen.

Un mini-submersible a controle a distance a été utilisé pour acquérir des images video en couleur du fond marin au-dessus des longues tailles de Phallen. Ces images ont été utilisé pour confirmer la présence d'un substratum rocheux sur le fond marin ainsi que les microtopographie complexe indiqué par les rapports bathymétrique. La présence d'affleurement de substratum sur le fond marin nous assure que les changement de la topographie sous marine sont le resultat d'activité miniere et non de transport de sédiment.

Cette étude montre de toute évidence que la subsidence du fond marin a été induite par l'activité minière. L'emplacement et la magnitude de c'est observation de subsidence sont documenté dans ce rapport. Ces données empirique sont nécessaire pour calculer les contraintes extensile de la masse rocheuse au-dessus du filon Phalen et évaluer la validité des directives minière courante.

SEAFLOOR TOPOGRAPHY OVER THE PHALEN COLLIERY,
PHASE 3 - 1989
SYDNEY COALFIELD
CAPE BRETON, NOVA SCOTIA

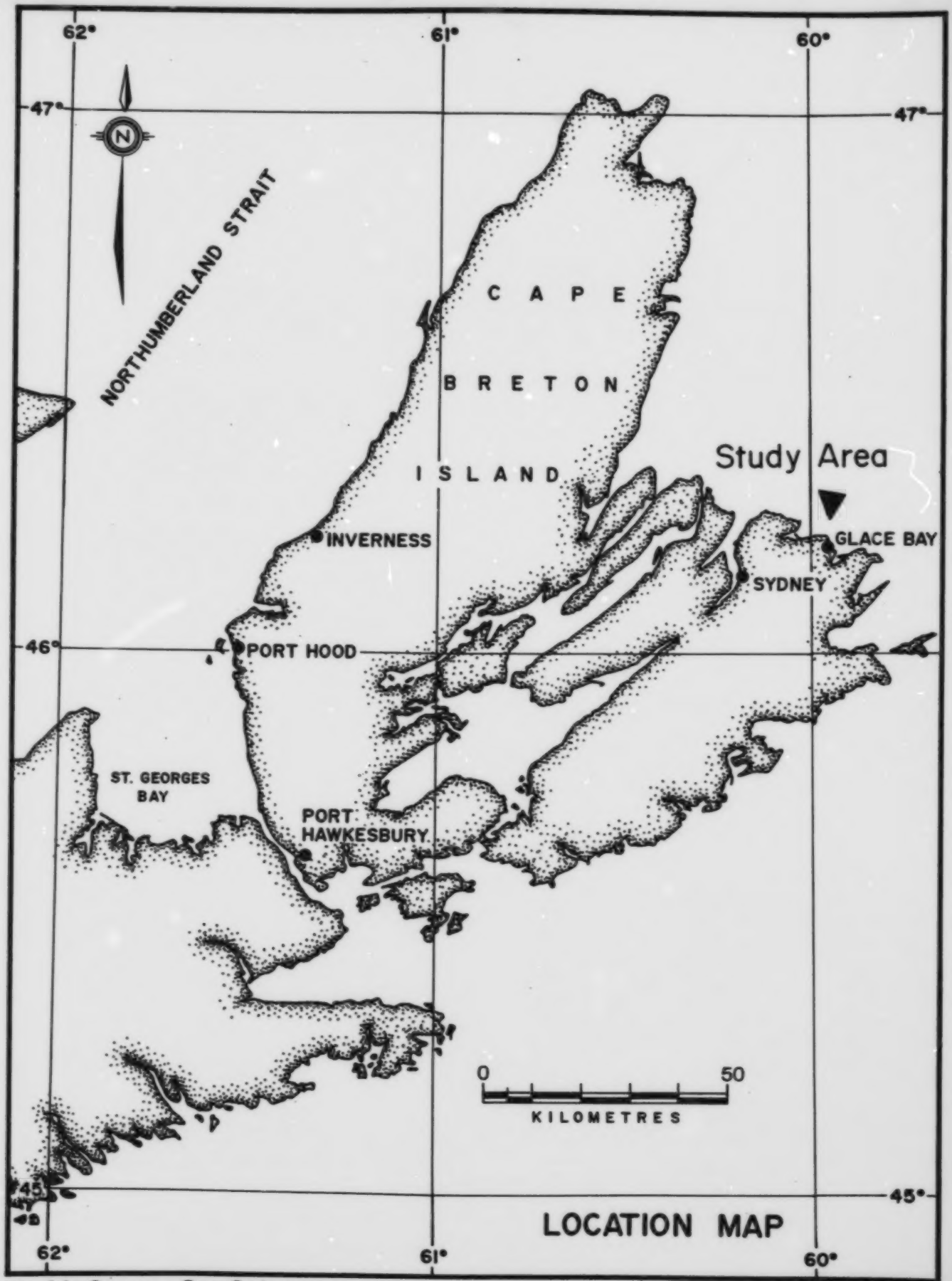
INTRODUCTION

The third phase of a multi-year study to evaluate mining induced seafloor subsidence was conducted by McGregor GeoScience Limited on behalf of Canada Centre for Mineral and Energy Technology (CANMET), Cape Breton Coal Research Laboratory. A 59 line kilometre grid of high resolution echosounder data was collected over the Cape Breton Development Corporation's Phalen Colliery, offshore New Waterford (Figure 1).

The aim of this study is to establish pre- and post-mining seafloor topography overlying longwall panels and examine the resulting profiles for evidence of subsidence resulting from excavation.

Color video images of the seafloor were also collected over portions of the survey area using a submersible remotely operated vehicle (R.O.V.).

Detailed in this report are the methods by which the data was collected, processed and analyzed, along with the results and conclusions which can be drawn from the data which is presently available.



McGregor GeoScience Limited

FIGURE 1

SECTION 1

SURVEY GRID AND MINEPLAN GEOMETRY

Section 1.1 Grid Survey

The 1989 bathymetric and R.O.V. track plots over the East and West Phalen sites are displayed in Figures 2a (Enclosure 1) and 2b (Enclosure 2). These maps are differentiated based on line survey direction. Figure 2a (Enclosure 1) display all south- and west-headed lines, while Figure 2b (Enclosure 2) display the north- and east-headed lines. The R.O.V. tracks are displayed in Figure 2c (Enclosure 3).

The overlying 1987, 1988 and 1989 survey lines were collected along a grid which is oriented parallel and perpendicular to the Phalen Colliery longwalls. Figures 3a and 3b detail the coincidence of the 1989 track lines with the 1987 and 1988 survey grids respectively. Figure 4 illustrates the mineplan geometry and the ideal track lines of the 1987, 1988 and 1989 survey. The date which mining occurred immediately beneath these track lines is also shown in Figure 4.

Due to the linear nature of the outcropping seafloor structure, the track lines oriented perpendicular to the longwalls, (and bathymetric strike), provide the most valuable data, since small deviations from the ideal survey centre line generally result in only minor bathymetric changes. Profile data collected on lines which run parallel to the longwalls (and the bathymetric contours) are much more sensitive to minor variations in the ideal track line due to the high degree of bathymetric variability along dip.

Weather related constraints dictated that data collection along the north-south trending lines be of primary importance. These lines are presently more valuable as subsidence indicators over a multi-year survey then are the strike lines. This prioritization allowed all of the north-south trending lines, with the exception of line 8907N, to be collected. East-west lines were only collected along lines 9, 22 and 23. These strike lines cover all of the actively mined longwalls to the survey date.

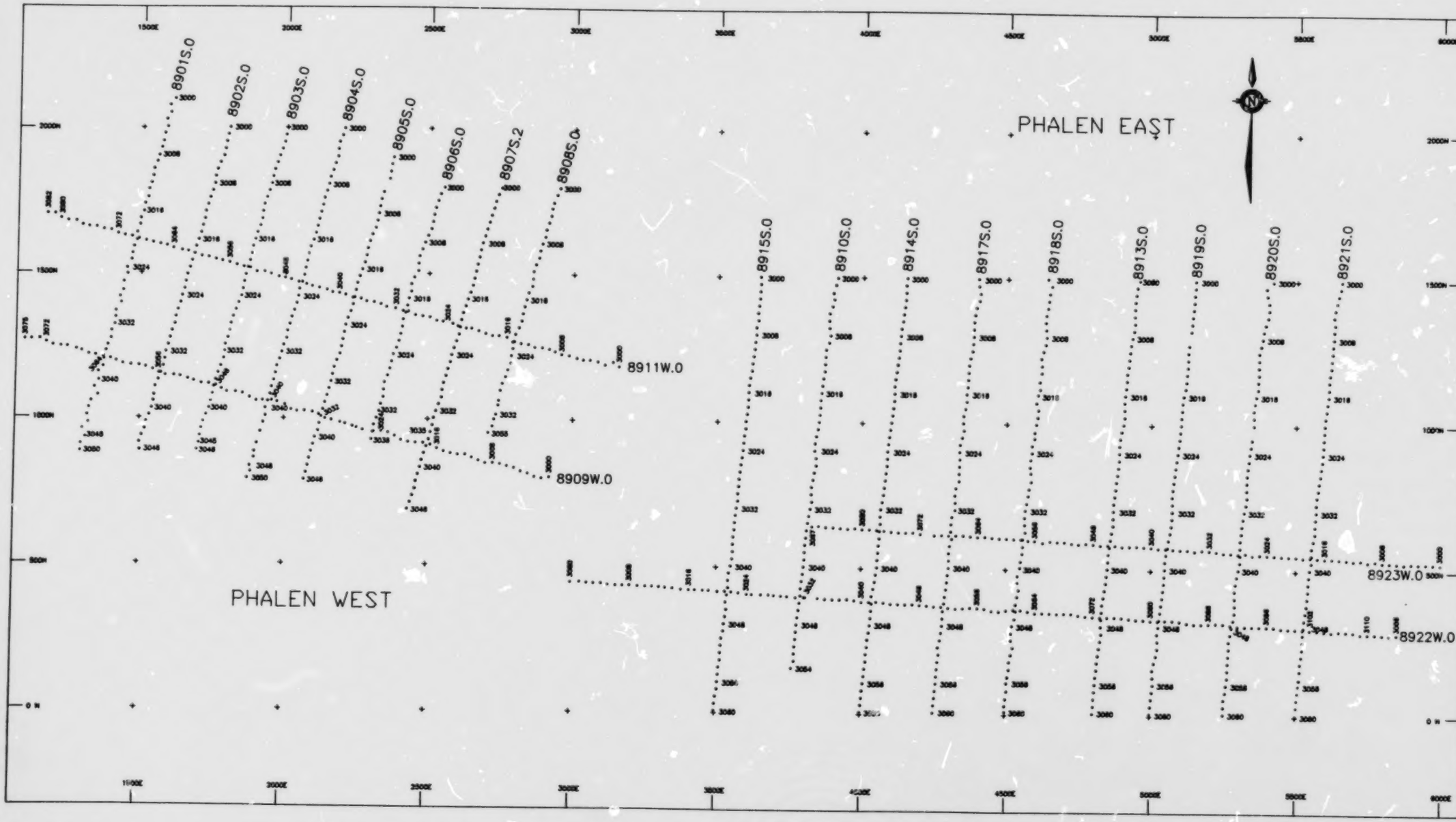
A summary of the data acquired along the 1989 track lines is presented in Table 1.

Table 1

Data Acquired along the 1989 Track Lines

Site	Line Trend	Nominal Length	Subtotal
West Phalen	North-South	1.25 km X 15 lines	18.75 km
	East-West	2.00 km X 2 lines	4.00 km
East Phalen	North-South	1.50 km X 18 lines	27.00 km
	East-West	1.00 km X 3 lines	9.00 km
		Total	58.75 km

While the West Phalen track lines cross the Number 1, 2 and 3 longwalls, active mining up to the date of the survey occurred only along the West Phalen No. 1 panel. Similarly the East Phalen track lines cross above the Number 1, 2, 3, 4 and 5 East Phalen longwall panels, however only the Number 1 and part of the Number 2 panels were mined as of the 1989 survey.



NOTES:

1. THE SURVEY WAS PERFORMED USING A DEL NORTE UHF TRESPONDER SYSTEM, CONSISTING OF FOUR REMOTE TRANSPONDERS AND A MASTER UNIT WITH BACK UP COMPONENTS, INTEGRATED WITH A REAL TIME NAVIGATION PACKAGE. THE TRESPONDER WAS CALIBRATED AND CHECKED ON SITE.
2. REMOTE TRANSPONDERS WERE LOCATED ON SURVEY MONUMENTS 1574, 1444 AND 1972R, AND A FOURTH STATION PREVIOUSLY ESTABLISHED FROM SURVEY MONUMENTS 1177 AND 1178.
3. THE MASTER ANTENNA ON BOARD THE SURVEY VESSEL WAS MOUNTED WITHIN 3m OF THE ECHO SOUNDER TRANSDUCER. POSITIONS PLOTTED REPRESENT THE ECHO SOUNDER TRANSDUCER POSITION.
4. THE SURVEY WAS PERFORMED USING THE CSDC LOCAL GRID. ALL DATA REPRESENTED ON THIS PLAN IS GIVEN IN THIS GRID. THE CSDC LOCAL GRID COORDINATE VALUES FOR THE ABOVE MONUMENTS WERE OBTAINED FROM CSDC.
5. THE FOLLOWING SYMBOLS INDICATE THE ATTEMPTS AT RUNNING THE SURVEY LINES

8906S.0 — LINE TRACK WITH FIX AND LINE NUMBER TO FIRST ATTEMPT.

8907S.2 — LINE TRACK WITH FIX AND LINE NUMBER TO CHECKING ATTEMPT.

NOTE THAT THE LINE 8908S.A IS PLOTTED AS 8908S.0

SCALE (m)
0 250 500

McGregor GeoScience Ltd.
Halifax, Nova Scotia

CANMET
CAPE BRETON COAL RESEARCH LABORATORY

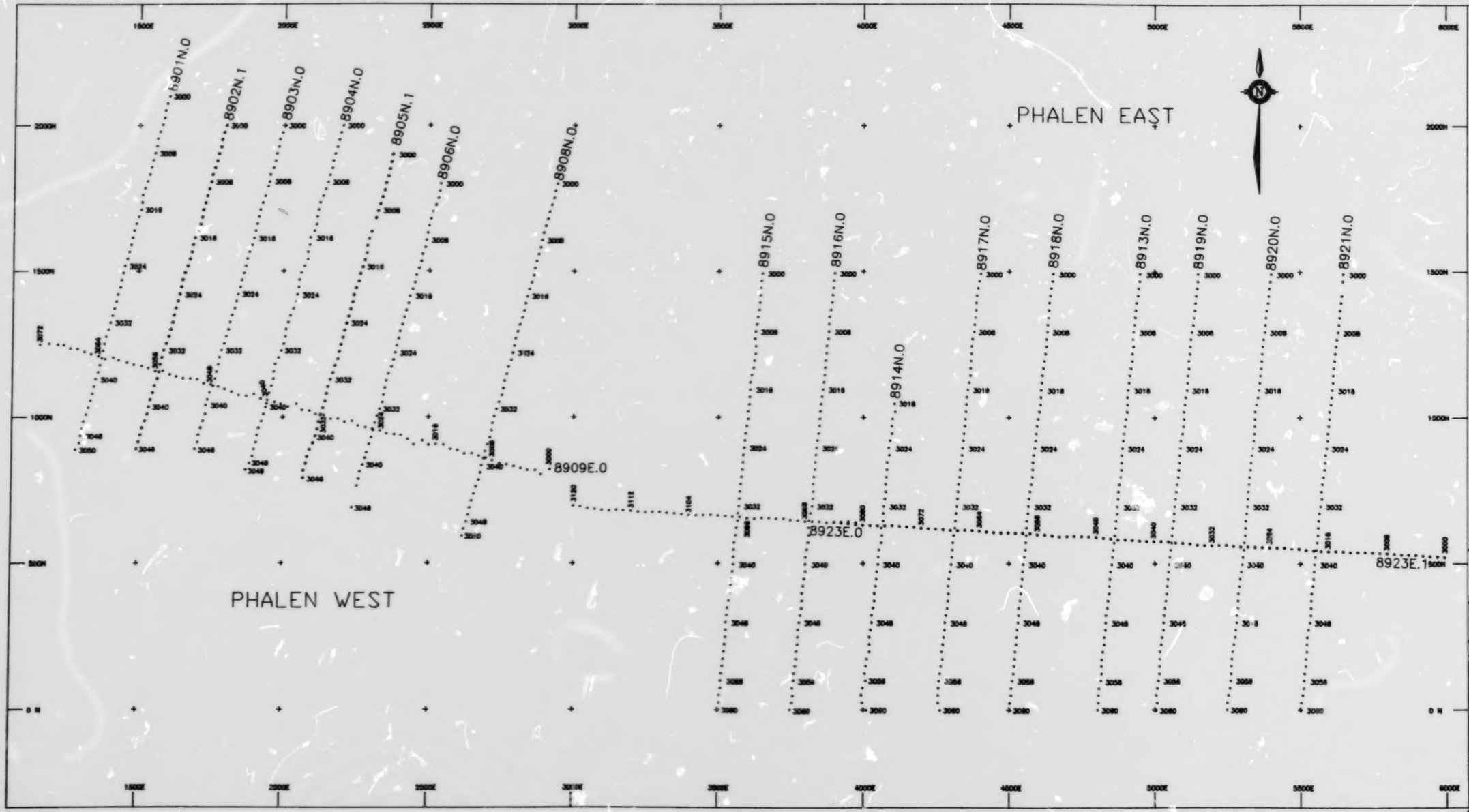
PHALEN MINES
SUBSIDENCE STUDY – 1989

SOUTH AND WEST RUN LINES

NORTECH ATLANTIC LTD.

Projection: DEVCO GRID UTM MODIFIED
Date: September 1989 | Project: 89-30
Enclosure: 1

FIGURE 2a



NOTES:

1. THE SURVEY WAS PERFORMED USING A DEL NORTE UHF TRISPONDER SYSTEM, CONSISTING OF FOUR REMOTE TRANSPONDERS AND A MASTER UNIT WITH BACK UP COMPONENTS, INTEGRATED WITH A REALTIME NAVIGATION PACKAGE. THE TRISPONDER WAS CALIBRATED AND CHECKED ON SITE.
2. REMOTE TRANSPONDERS WERE LOCATED ON SURVEY MONUMENTS 1574, 1614 AND 1972R, AND A FOURTH STATION PREVIOUSLY ESTABLISHED FROM SURVEY MONUMENTS 1177 AND 1178.
3. THE MASTER ANTENNA ON BOARD THE SURVEY VESSEL WAS MOUNTED WITHIN 2m OF THE ECHO SOUNDER TRANSDUCER. POSITIONS PLOTTED REPRESENT THE ECHO SOUNDER TRANSDUCER POSITION.
4. THE SURVEY WAS PERFORMED USING THE CBDC LOCAL GRID. ALL DATA REPRESENTED ON THIS PLAN IS GIVEN IN THIS GRID. THE CBDC LOCAL GRID COORDINATE VALUES FOR THE ABOVE MONUMENTS WERE OBTAINED FROM CBDC.
5. THE FOLLOWING SYMBOLS INDICATE THE ATTEMPTS AT RUNNING THE SURVEY LINES

8901N.0 — LINE TRACK WITH FIX AND LINE NUMBER TO (FIRST ATTEMPT).

8902N.1 — LINE TRACK WITH FIX AND LINE NUMBER TO (SECOND ATTEMPT).

SCALE (m)
0 250 500

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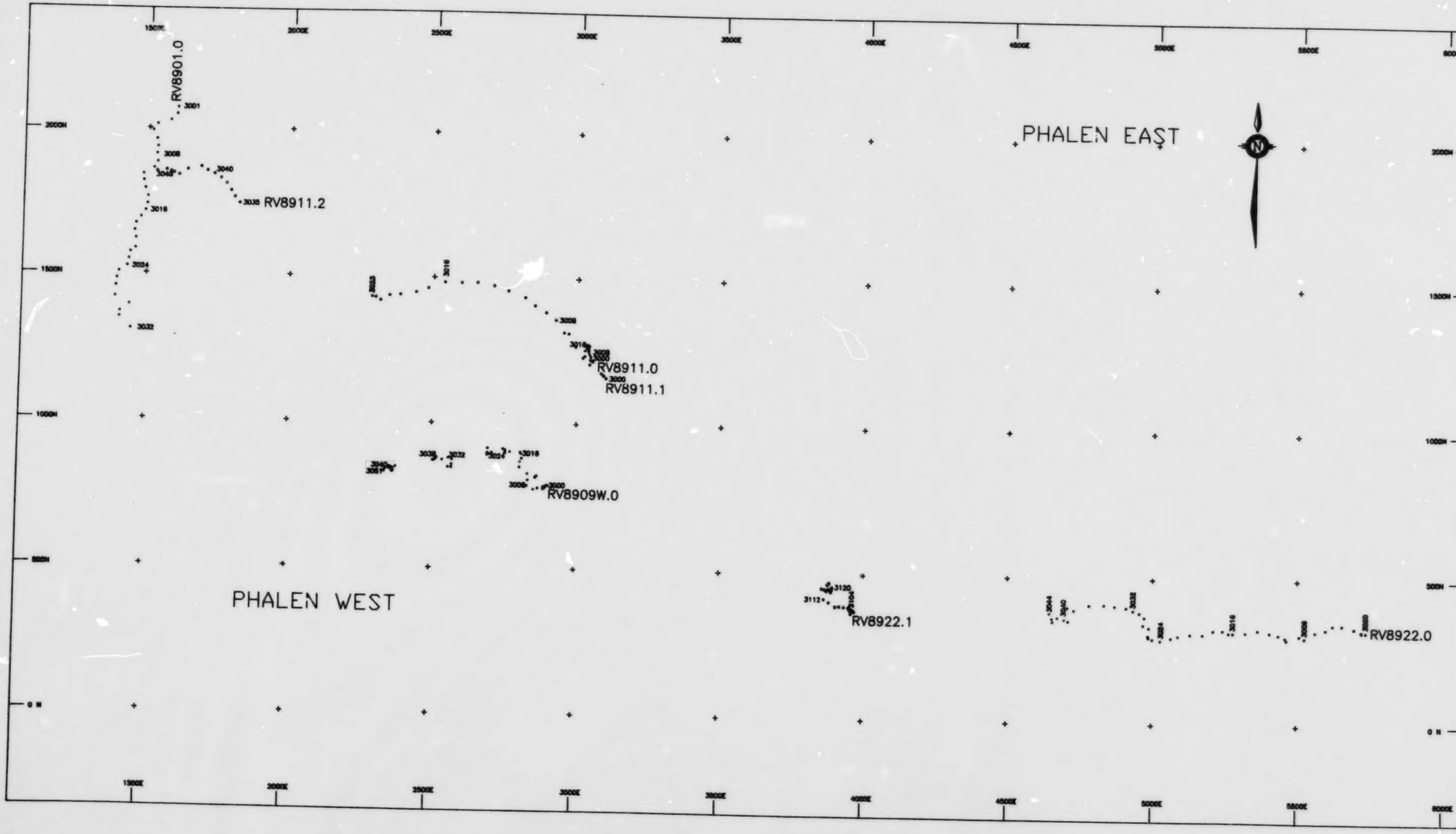
PHALEN MINES
SUBSIDENCE STUDY – 1989

NORTH AND EAST RUN LINES

NORTECH ATLANTIC LTD.

Projection: DEVCO GRID UTM MODIFIED	
Date: September 1989	Project: 89-30
Scale :	Enclosure: 2

FIGURE 2b



NOTES:

1. THE SURVEY WAS PERFORMED USING A DEL NORTE UHF TRANSPONDER SYSTEM CONSISTING OF FOUR REMOTE TRANSPONDERS AND A MASTER UNIT WITH BACK UP COMPONENTS, INTEGRATED WITH A REALTIME NAVIGATION PACKAGE. THE TRANSPONDER WAS CALIBRATED AND CHECKED ON SITE.
2. REMOTE TRANSPONDERS WERE LOCATED ON SURVEY MONUMENTS 1074, 1044 AND 1973B AND A FOURTH STATION PREVIOUSLY ESTABLISHED FROM SURVEY MONUMENTS 1177 AND 1178.
3. THE MASTER ANTENNA ON BOARD THE SURVEY VESSEL WAS MOUNTED WITHIN 3m OF THE ECHO SOUNDER TRANSDUCER. POSITIONS PLOTTED REPRESENT THE ECHO SOUNDER TRANSDUCER POSITION.
4. THE SURVEY WAS PERFORMED USING THE CSRC LOCAL GRID. ALL DATA REPRESENTED ON THIS PLAN IS GIVEN IN THIS GRID. THE CSRC LOCAL GRID COORDINATE VALUES FOR THE ABOVE MONUMENTS WERE OBTAINED FROM CSRC.
5. THE FOLLOWING SYMBOLS INDICATE THE ATTEMPTS AT RUNNING THE SURVEY LINES

   PRIMARY RUN :
   SECONDARY RUN :

NOTE: RV8909V IS A COMPOSITE PLOT OF RV8909V.0, RV8909V.1, RV8909V.2, RV8909V.3

SCALE (m)
0 250 500

McGregor GeoScience Ltd.
Halifax, Nova Scotia

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CAPE BRETON COAL RESEARCH LABORATORY

PHALEN MINES
SUBSIDENCE STUDY – 1989

ROV LINES

NORTECH ATLANTIC LTD.

Projection: DEVCO GRID UTM MODIFIED	
Date: September 1989	Project: 88-30
Scale :	Enclosure: 3

FIGURE 2c

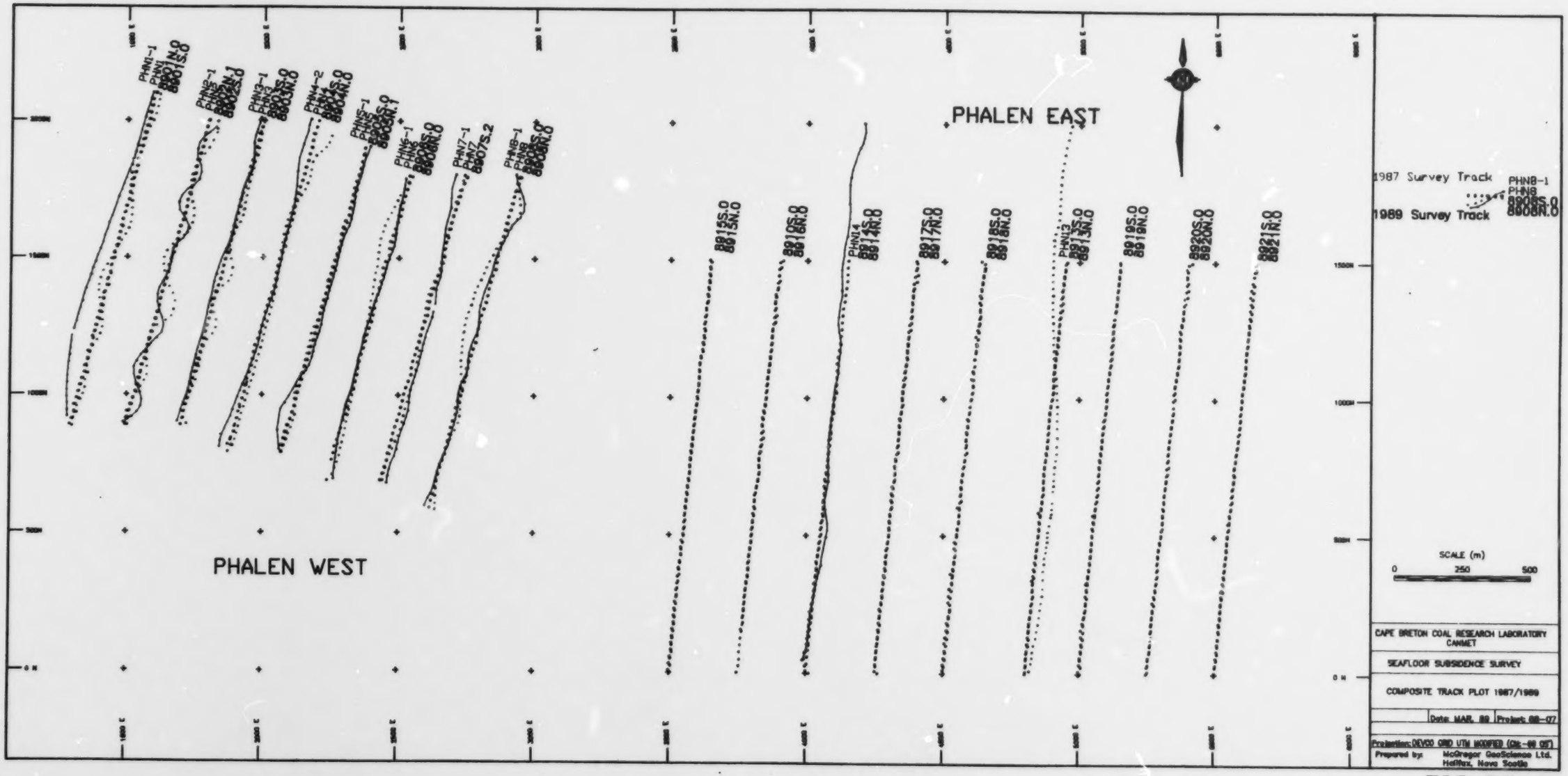

PHALEN EAST
PHALEN WEST
PHN1-1
PHN1
8801S.0
8801N.0
PHN2-1
PHN2
8802S.0
8802N.0
PHN3-1
PHN3
8803S.0
8803N.0
PHN4-2
PHN4
8804S.0
8804N.0
PHN5-1
PHN5
8805S.0
8805N.0
PHN6-1
PHN6
8806S.0
8806N.0
PHN7-1
PHN7
8807S.2
PHN8-1
PHN8
8808S.0
8808N.0
8812S.0
8812N.0
8816S.0
8816N.0
PHN14
8814S.0
8814N.0
8817S.0
8817N.0
8818S.0
8818N.0
PHN13
8813S.0
8813N.0
8819S.0
8819N.0
8820S.0
8820N.0
8821S.0
8821N.0
1987 Survey Track
PHN8-1
PHN8
8808S.0
8808N.0
1989 Survey Track
SCALE (m)
0
250
500
CAPE BRETON COAL RESEARCH LABORATORY
CANMET
SEAFLOOR SUBSIDENCE SURVEY
COMPOSITE TRACK PLOT 1987/1989
Date: MAR. 89
Project: 88-07
Projection: DEVCO GRID UTM MODIFIED (Clk:-60 00')
Prepared by: McGregor GeoScience Ltd.
Halifax, Nova Scotia

FIGURE 3a

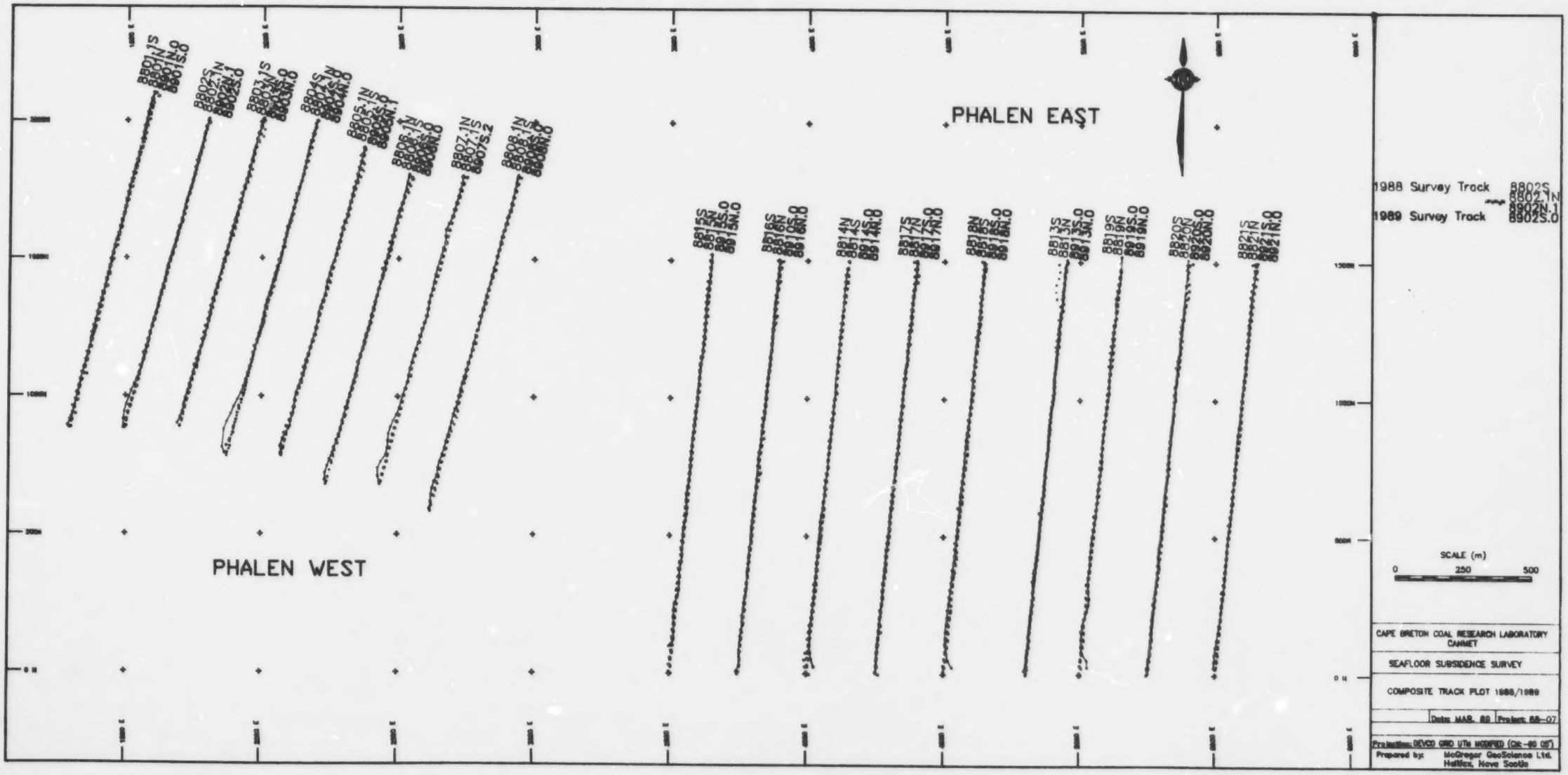
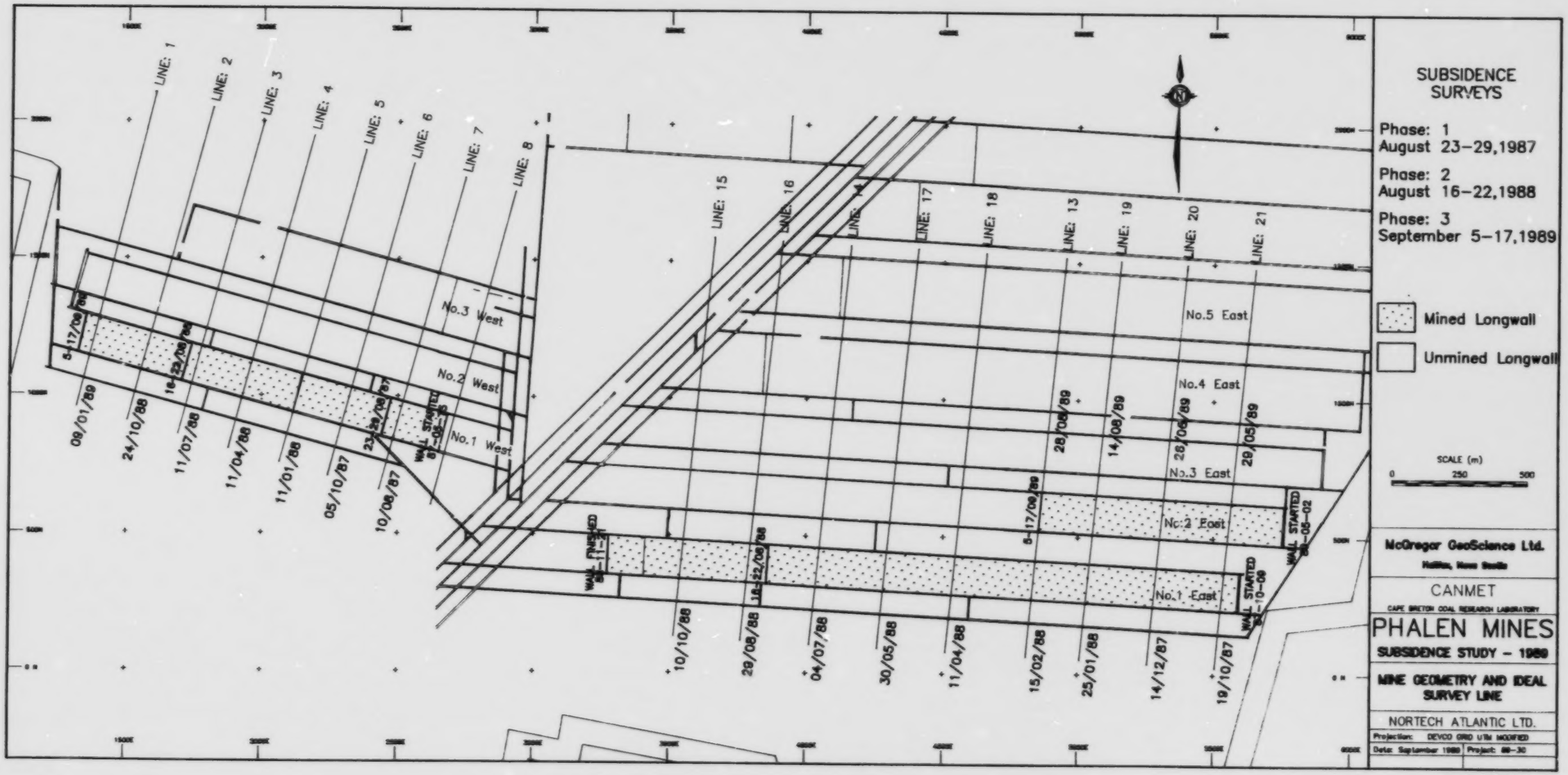

PHALEN EAST
PHALEN WEST
1988 Survey Track 8802S
8802.1N
1989 Survey Track 8902N.1
8902S.0
SCALE (m)
0 250 500
CAPE BRETON COAL RESEARCH LABORATORY
CANMET
SEAFLOOR SUBSIDENCE SURVEY
COMPOSITE TRACK PLOT 1988/1989
Date: MAR. 89 Project: 88-07
Projection: DEVCO GRID UTM MODIFIED (Cm: -60 00')
Prepared by: McGregor GeoScience Ltd.
Halifax, Nova Scotia

FIGURE 3b


LINE: 1
LINE: 2
LINE: 3
LINE: 4
LINE: 5
LINE: 6
LINE: 7
LINE: 8
LINE: 15
LINE: 16
LINE: 14
LINE: 17
LINE: 18
LINE: 13
LINE: 19
LINE: 20
LINE: 21
No.3 West
No.2 West
No.1 West
No.5 East
No.4 East
No.3 East
No.2 East
No.1 East
09/01/89
24/10/88
11/07/88
11/04/88
11/01/88
05/10/87
10/08/87
10/10/88
29/08/88
04/07/88
30/05/88
11/04/88
15/02/88
25/01/88
14/12/87
19/10/87
28/06/89
14/06/89
26/05/89
29/05/89
WALL STARTED 87-05-26
WALL FINISHED 87-11-11
WALL STARTED 88-10-06
WALL STARTED 89-05-02
N
SUBSIDENCE SURVEYS
Phase: 1
August 23-29,1987
Phase: 2
August 16-22,1988
Phase: 3
September 5-17,1989
Mined Longwall
Unmined Longwall
SCALE (m)
0 250 500
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Halifax, Nova Scotia
CANMET
CAPE BRETON COAL RESEARCH LABORATORY
PHALEN MINES
SUBSIDENCE STUDY - 1989
MINE GEOMETRY AND IDEAL SURVEY LINE
NORTECH ATLANTIC LTD.
Projection: DEVCO GRID UTM MODIFIED
Date: September 1989
Project: 89-30

FIGURE 4

SECTION 2

DATA PROCESSING

Section 2.1 Track Plots

Survey vessel navigation was provided by Nortech Surveys in the form of Autocad drawing files, mylar track plots, and ASCII files. These ASCII files consist of line name, Devco grid coordinate and a fix number. The Devco grid position and the fix positions, annotated on the bathymetric profiles, are thereby directly related.

Section 2.2 Bathymetric Processing

Section 2.2.1 Digitization

The echosounder profiles were digitized directly using Petrospec data capture software. The fixed recording speed of the echosounder combined with the often variable travel time between equally spaced fix positions resulted in a variable horizontal scale on the bathymetric records. This distortion was corrected for by scaling the profile fix positions to the navigation fix positions. The exact position of the latter was obtained from the navigation files.

The merging of the profile and plan data sets was accomplished using Supertec mapping software. This software combines the plan and profile data sets by plotting the navigational data at a constant scale, then matching the digital profile data to the navigation file based on fix positions along line. The profile was then output by Supertec to an Autocad ASCII drawing interchange file (DXF format) at a constant vertical exaggeration of 1:20. This format is consistant with the

previous years' surveys and allows for direct multi-year profile comparisons.

Section 2.2.2 Tide Correction

Tidal corrections applied to the bathymetric profiles were obtained from the Marine Environmental Data Service (MEDS), Ottawa and pertain to the North Sydney permanent tidal station. These values are considered valid due to the stations proximity to the survey site. The brief duration (approximately 15 minutes) of the survey lines facilitated a single bulk shift correction for each line. Tide information in available in Appendix 2 (Table 2-3). These shifts proved satisfactory in most cases, and produce exact overlaps the north and south headed profiles. In some cases however this shift was not sufficient. In these situations the profile in question was vertically shifted to align distinct topographic features identifiable on both traverses. This is reasonable as long as the features matched are distant from any mining activity and the corresponding track lines are coincident in plan. The magnitude and direction of these additional shifts are readily ascertained by comparison of the composite Autocad drawings with the uncorrected field recorded water depths. These uncorrected depths are located in a dBase IV compatible database, which resides with the Scientific Authority. Storm surges during the survey period may have resulted in the inappropriate tidal corrections in some cases.

Section 2.3 Plan and Profile AutoCad Drawing Development

Production of the 1989 panels involved four principal steps:

1) Importing the Supertec ASCII drawing interchange files (DXF) into Autocad drawing files.

2) Merging the profiles representing the north and south traverses for each line.

3) Merging the navigational track lines corresponding to each of the profiles according to their superposition within the Devco grid.

4) Combining the plan and profile drawings in the final version of the panel, with alignment of the plans and profiles drawings based on correlating the fix positions in the profiles with the respective fix positions in the overlying tracks lines.

This procedure was completed for 1989 lines 1 to 8 and lines 13 to 21 resulting in an individual panel containing the bathymetry for the north and south traverses over each line along with their corresponding navigational track superimposed over these profiles. A vertical exaggeration of 1:20 was maintained for all of the profiles. The completed 1989 panel set can be observed in Figures 5 to 21, with a full scale (1:1000 horizontal, 1:50 vertical scale) version of line 16 presented as Enclosure 4.

Subsidence determinations require that corresponding profiles from different years be compared to identify areas of anomalous depressions within the proximity of the longwalls. The standardized horizontal and vertical scales applied to the previous years panel drawings, as well as the 1989 panels, allows these comparisons to be accomplished directly in Autocad by overlaying and aligning panel drawings from selected years.

The complexities involved in trying to overlap and present 6 lines representing three years of data collection proved inadequate for display purposes. For this reason comparisons were performed between all of the 1989 and 1988 panels separately from the 1989 and 1987 panels. The 1988 subsidence report (McGregor, 1989) provides direct overlap displays of the 1988 and 1987 profiles. The 1987/1989 profile overlays can be observed in Figures 22 to 31. The 1988/1989 profile overlays are also presented in Figures 32 to 48.

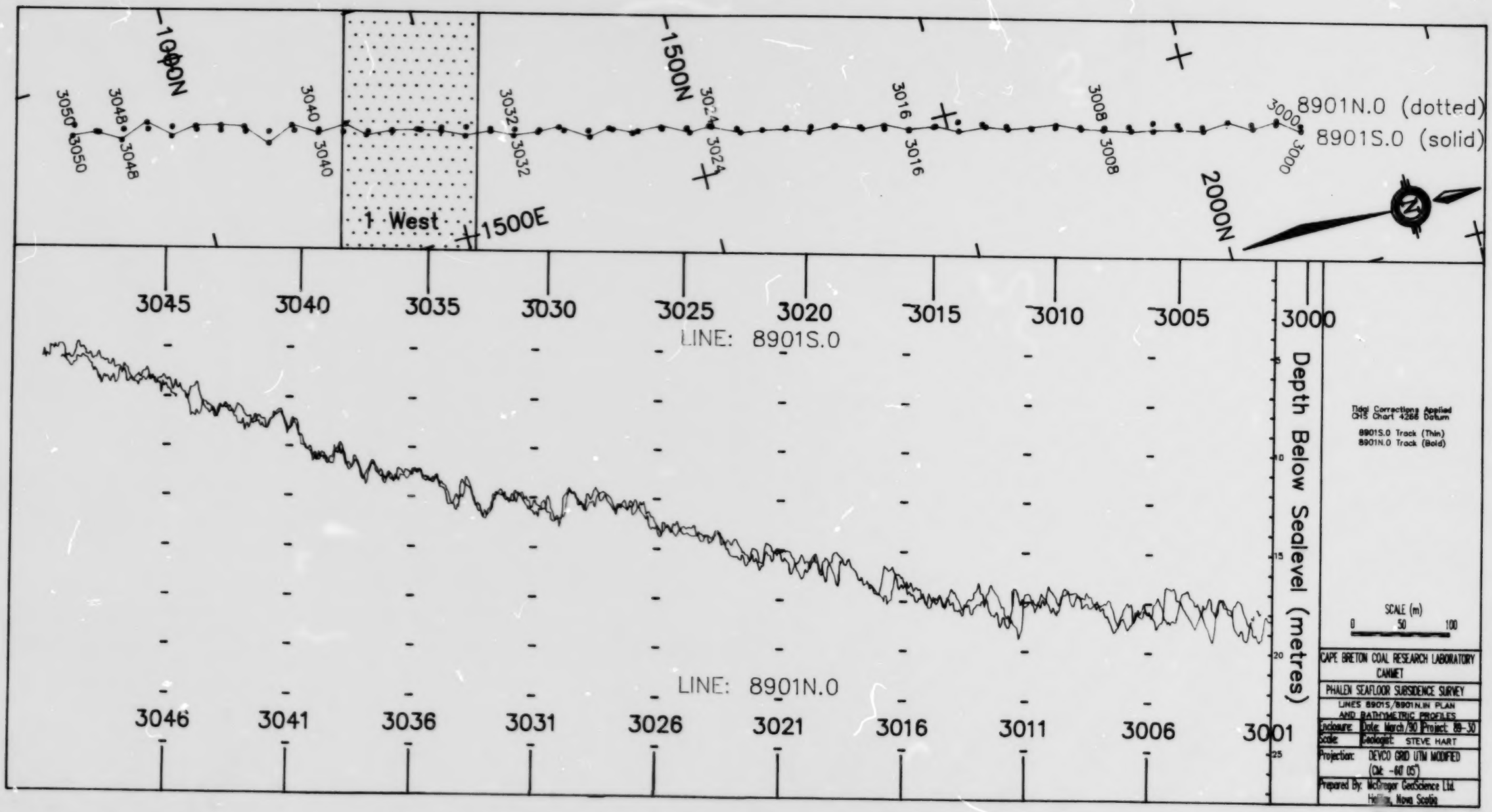

1000N
1500N
2000N
1 West
1500E
3050
3048
3040
3032
3024
3016
3008
3000
8901N.0 (dotted)
8901S.0 (solid)
N
3045
3040
3035
3030
3025
3020
3015
3010
3005
3000
LINE: 8901S.0
LINE: 8901N.0
3046
3041
3036
3031
3026
3021
3016
3011
3006
3001
Depth Below Sealevel (metres)
10
15
20
25
Tidal Corrections Applied
CHS Chart 4266 Datum
8901S.0 Track (Thin)
8901N.0 Track (Bold)
SCALE (m)
0 50 100
CAPE BRETON COAL RESEARCH LABORATORY
CANMET
PHALEN SEAFLOOR SUBSIDENCE SURVEY
LINES 8901S/8901N.IN PLAN
AND BATHYMETRIC PROFILES
Enclosure: Date: March/90 Project: 89-30
Scale: Geologist: STEVE HART
Projection: DEVCO GRID UTM MODIFIED
(Dat: -60 05')
Prepared By: McGregor GeoScience Ltd.
Halifax, Nova Scotia

FIGURE 5

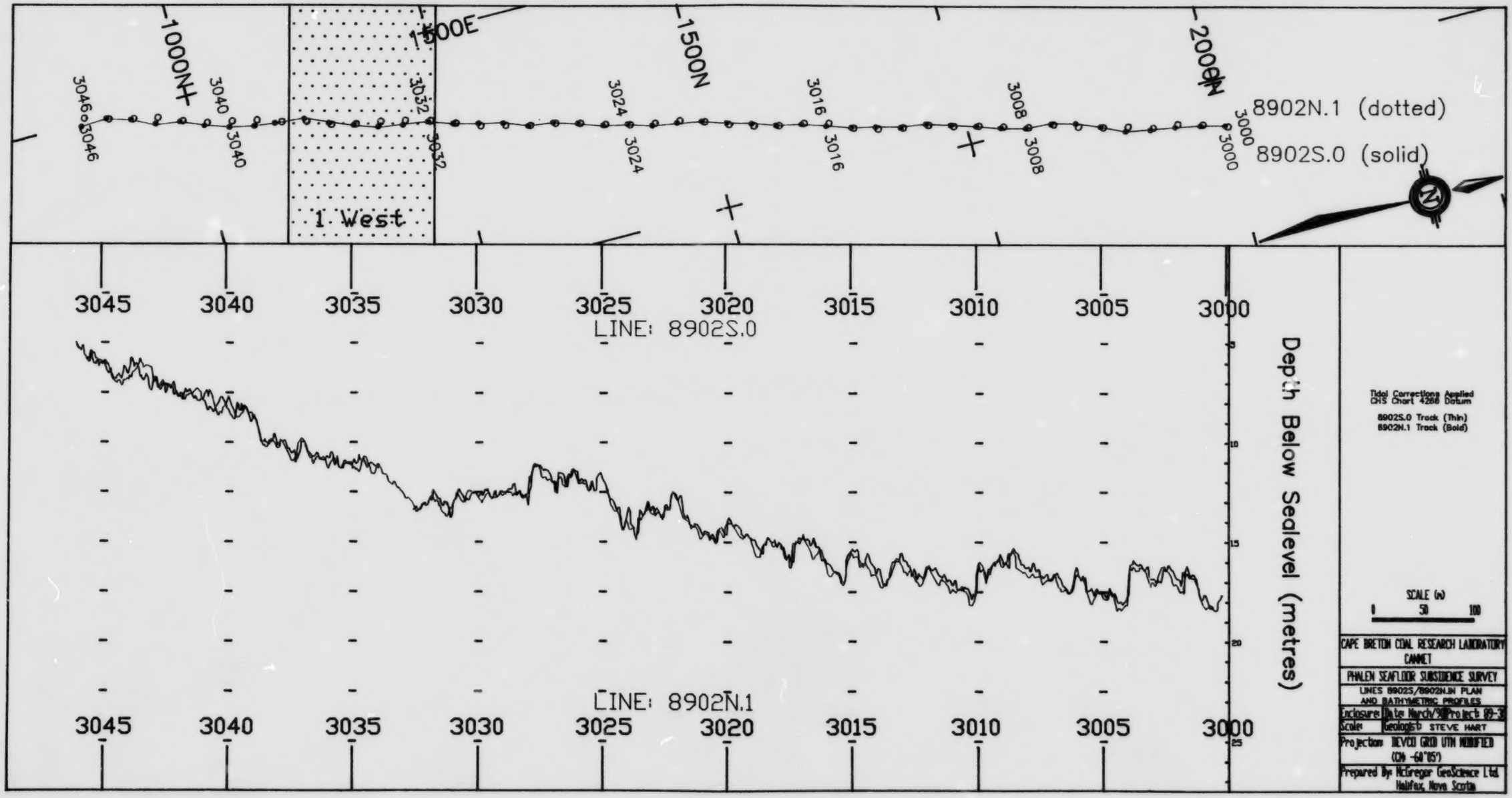

1000N
1500E
1500N
2000N
8902N.1 (dotted)
8902S.0 (solid)
1 West
3046
3040
3032
3024
3016
3008
3000
3045
3040
3035
3030
3025
3020
3015
3010
3005
3000
LINE: 8902S.0
LINE: 8902N.1
Depth Below Sealevel (metres)
Tidal Corrections Applied CHS Chart 4268 Datum
8902S.0 Track (Thin)
8902N.1 Track (Bold)
SCALE (m)
0 50 100
CAPE BRETON COAL RESEARCH LABORATORY CANMET
PHALEN SEAFLOOR SUBSIDENCE SURVEY
LINES 8902S/8902N.IN PLAN AND BATHYMETRIC PROFILES
Enclosure
Date March/98
Project 09-3
Scale
Geologist STEVE HART
Projection DEVCO GRID UTM MODIFIED (CM -60°05')
Prepared by McGregor GeoScience Ltd. Halifax, Nova Scotia

FIGURE 6

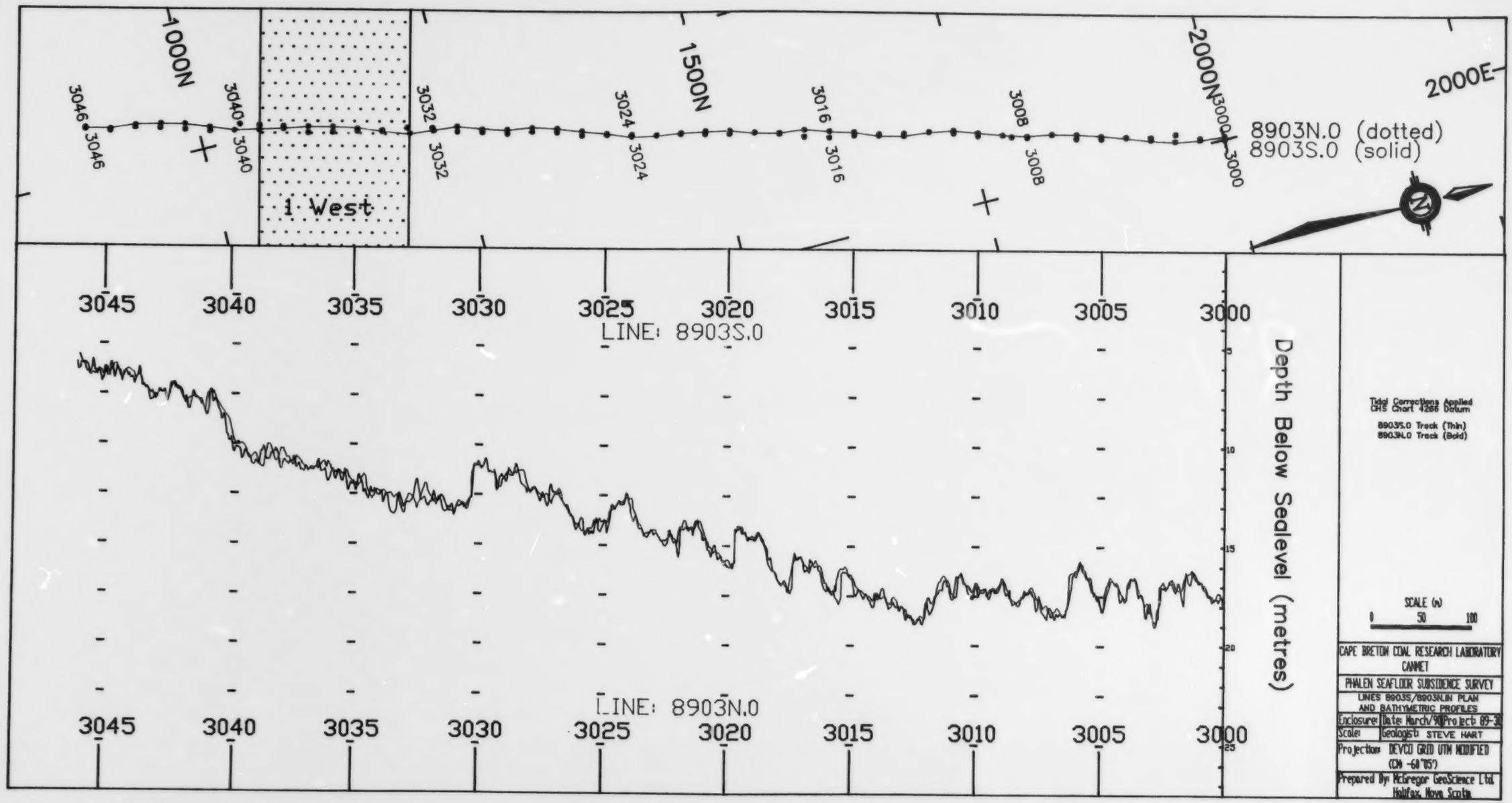

1000N
1500N
2000N
2000E
3046
3040
3032
3024
3016
3008
3000
8903N.0 (dotted)
8903S.0 (solid)
1 West
3045
3040
3035
3030
3025
3020
3015
3010
3005
3000
LINE: 8903S.0
LINE: 8903N.0
Depth Below Sealevel (metres)
0
5
10
15
20
25
Tidal Corrections Applied
CHS Chart 4266 Datum
8903S.0 Track (Thin)
8903N.0 Track (Bold)
SCALE (m)
0 50 100
CAPE BRETON COAL RESEARCH LABORATORY
CANMET
PHALEN SEAFLOOR SUBSIDENCE SURVEY
LINES 8903S/8903N,N PLAN
AND BATHYMETRIC PROFILES
Enclosure: Date: March/90 Project: 89-30
Scale: Geologist: STEVE HART
Projection: BEVCO GRID UTM MODIFIED
(CM -60°15')
Prepared by: McGregor GeoScience Ltd.
Halifax, Nova Scotia

FIGURE 7

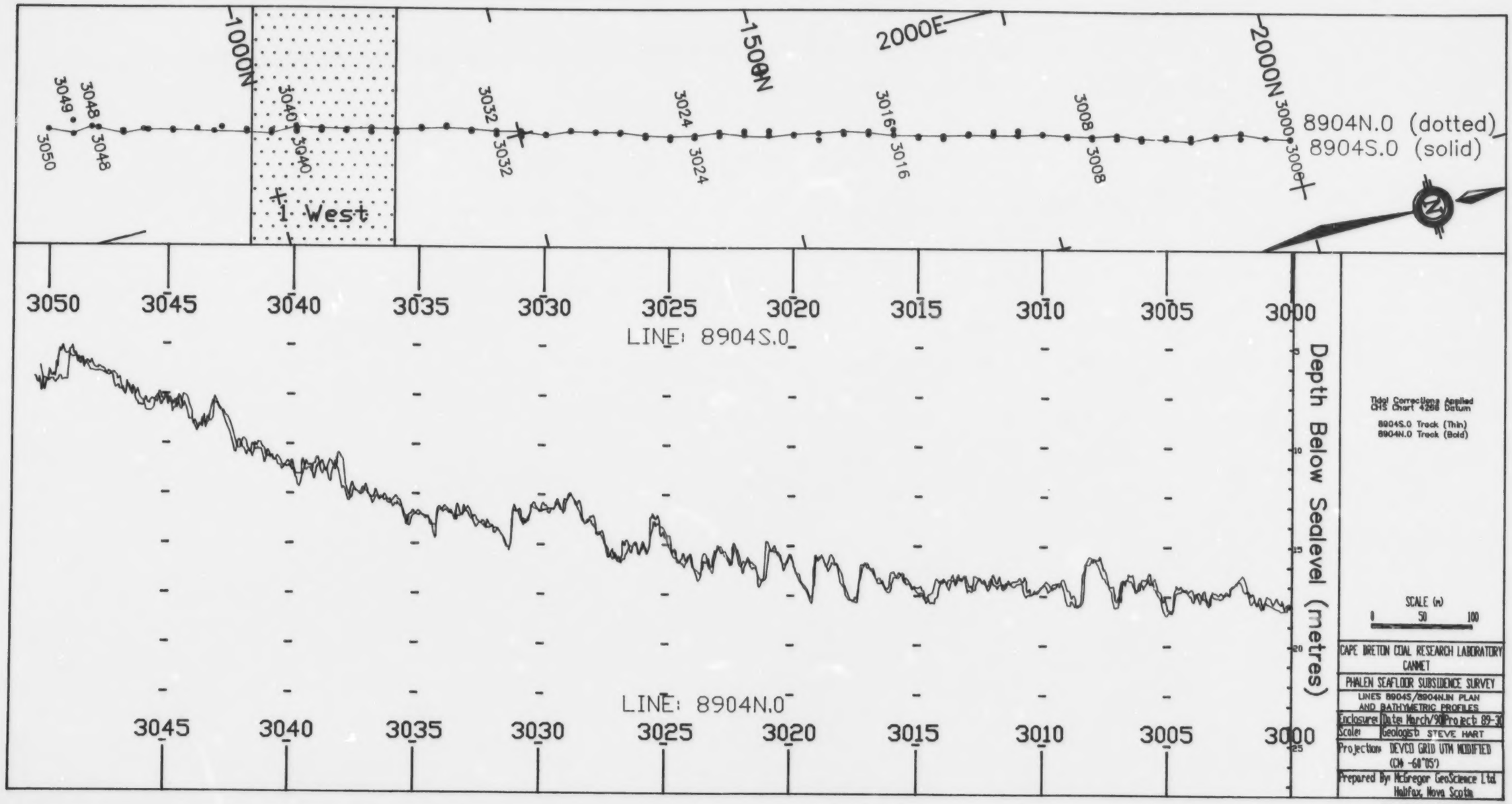

1000N
1500N
2000E
2000N
3049
3048
3050
3048
3040
3040
3032
3032
3024
3024
3016
3016
3008
3008
3000
3000
8904N.0 (dotted)
8904S.0 (solid)
1 West
3050
3045
3040
3035
3030
3025
3020
3015
3010
3005
3000
LINE: 8904S.0
LINE: 8904N.0
3045
3040
3035
3030
3025
3020
3015
3010
3005
3000
Depth Below Sealevel (metres)
Tidal Corrections Applied
CHS Chart 4298 Datum
8904S.0 Track (Thin)
8904N.0 Track (Bold)
SCALE (m)
0
50
100
CAPE BRETON COAL RESEARCH LABORATORY
CANMET
PHALEN SEAFLOOR SUBSIDENCE SURVEY
LINES 8904S/8904N.IN PLAN
AND BATHYMETRIC PROFILES
Enclosure
Date March/90
Project: 89-30
Scale:
Geologist: STEVE HART
Projection: DEVCO GRID UTM MODIFIED
(CM -60°05')
Prepared By: McGregor GeoScience Ltd.
Halifax, Nova Scotia

FIGURE 8

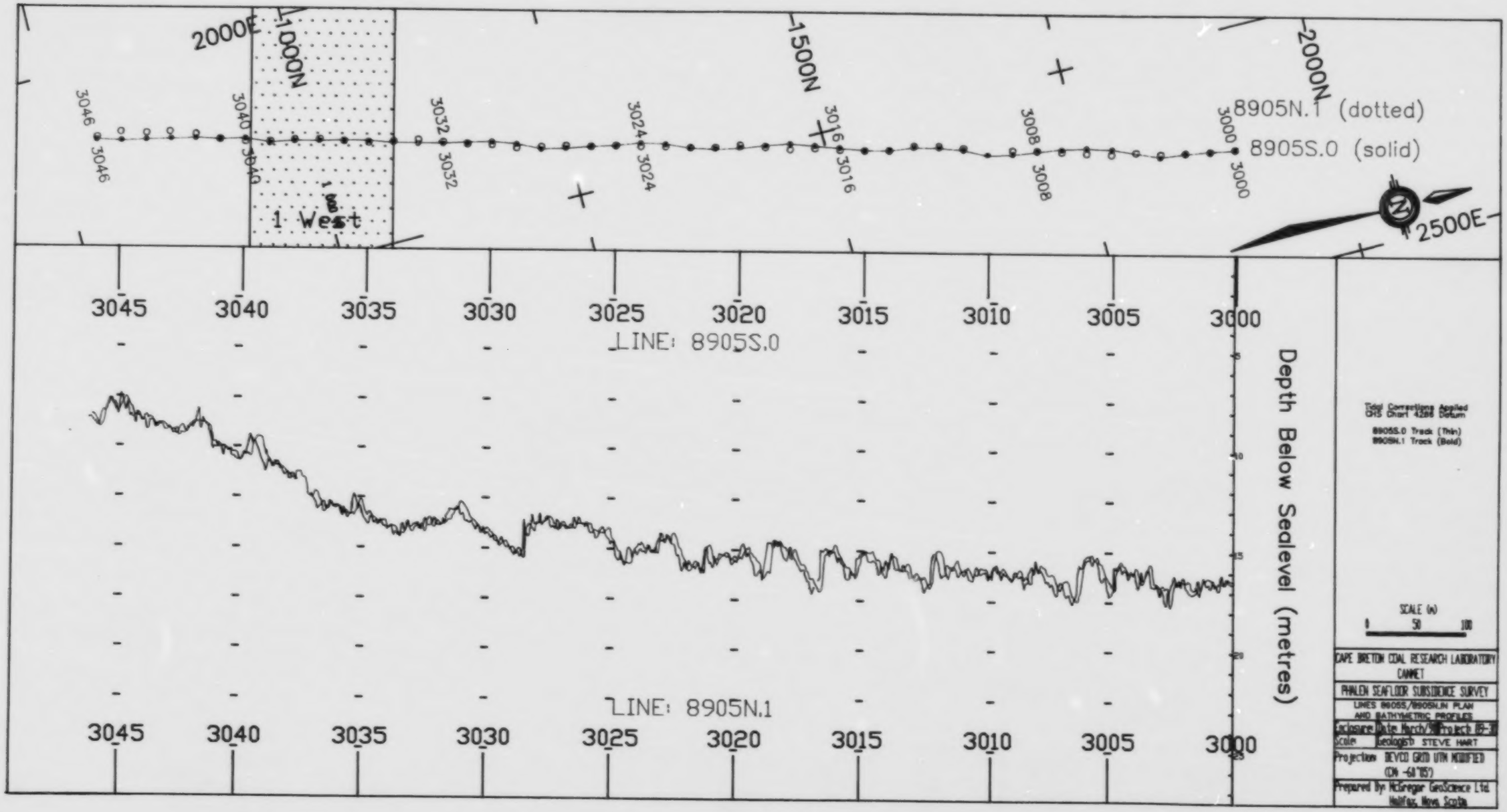

2000E
1000N
1500N
2000N
2500E
8905N.1 (dotted)
8905S.0 (solid)
3046
3040
3032
3024
3016
3008
3000
1 West
3045
3040
3035
3030
3025
3020
3015
3010
3005
3000
LINE: 8905S.0
LINE: 8905N.1
Depth Below Sealevel (metres)
Total Corrections Applied
CHS Chart 4268 Datum
8905S.0 Track (Thin)
8905N.1 Track (Bold)
SCALE (m)
0 50 100
CAPE BRETON COAL RESEARCH LABORATORY
CANMET
PHALEN SEAFLOOR SUBSIDENCE SURVEY
LINES 8905S/8905N.1N PLAN
AND BATHYMETRIC PROFILES
Scale
Geologist STEVE HART
Projection BEVCO GRID UTM MODIFIED
(DN -68°15')
Prepared by McGregor GeoScience Ltd.
Halifax, Nova Scotia

FIGURE 9

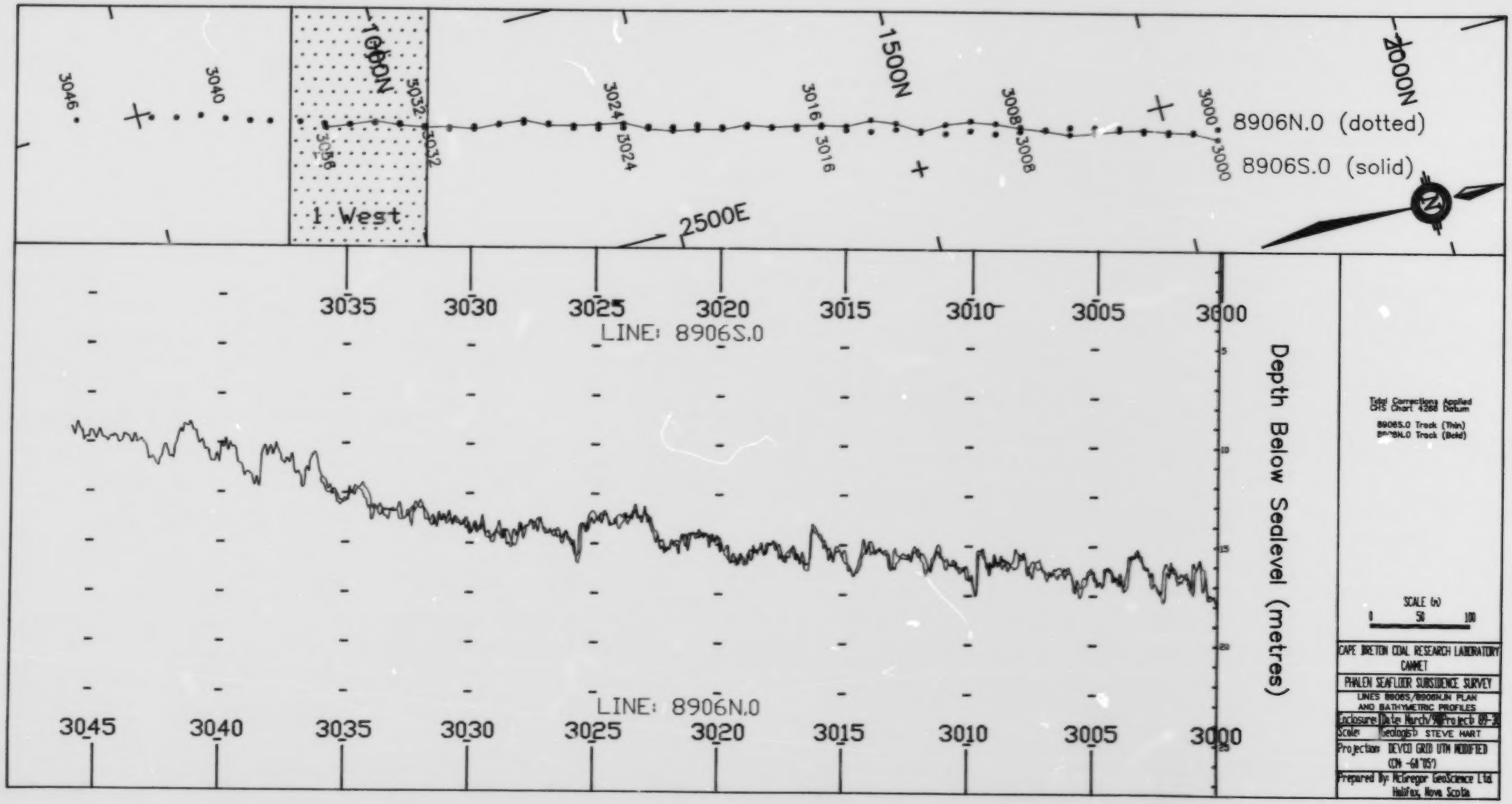

1000N
1500N
2000N
2500E
1 West
3046
3040
3032
3024
3016
3008
3000
8906N.0 (dotted)
8906S.0 (solid)
3035
3030
3025
3020
3015
3010
3005
3000
LINE: 8906S.0
LINE: 8906N.0
3045
3040
3035
3030
3025
3020
3015
3010
3005
3000
Depth Below Sealevel (metres)
Total Corrections Applied
CHS Chart 4268 Datum
8906S.0 Track (Thin)
8906N.0 Track (Bold)
SCALE (m)
0 50 100
CAPE BRETON COAL RESEARCH LABORATORY
CANMET
PHALEN SEAFLOOR SUBSIDENCE SURVEY
LINES 8906S/8906N.N PLAN
AND BATHYMETRIC PROFILES
Enclosure Date March/98 Project 69-2
Scale Geologist STEVE HART
Projection DEVCO GRID UTM MODIFIED
(CM= -60°15')
Prepared By: McGregor GeoScience Ltd.
Halifax, Nova Scotia

FIGURE 10

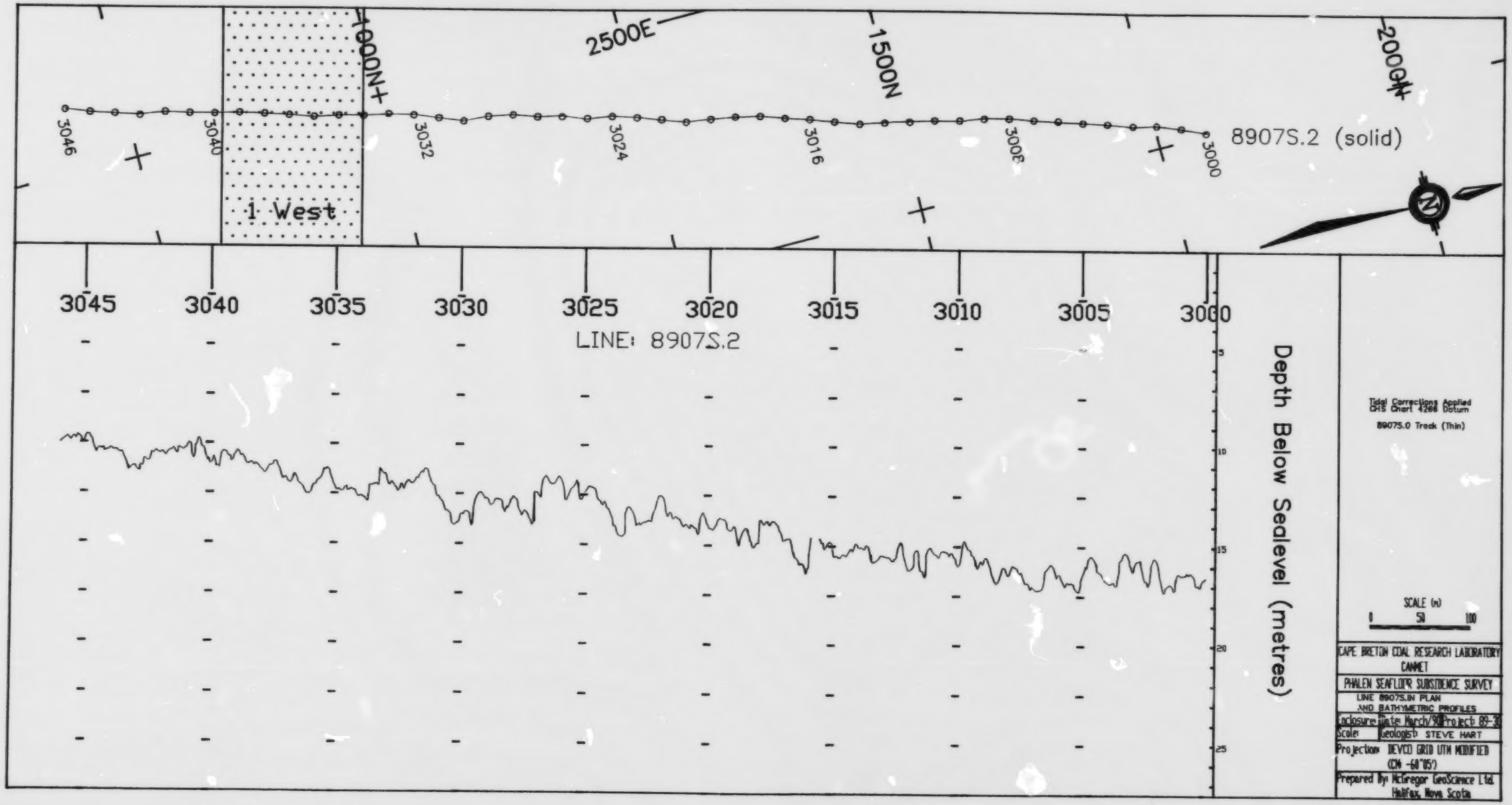

1000N
1500N
2000N
2500E
3046
3040
3032
3024
3016
3008
3000
8907S.2 (solid)
1 West
N
3045
3040
3035
3030
3025
3020
3015
3010
3005
3000
LINE: 8907S.2
Depth Below Sealevel (metres)
Tidal Corrections Applied
CHS Chart 4268 Datum
89075.0 Track (Thin)
SCALE (m)
0
50
100
CAPE BRETON COAL RESEARCH LABORATORY
CANMET
PHALEN SEAFLOOR SUBSIDENCE SURVEY
LINE 8907S.2N PLAN
AND BATHYMETRIC PROFILES
Enclosure
Date March/90
Project 89-30
Scale
Geologist STEVE HART
Projection
NEVCO GRID UTM MODIFIED
(CM -60°05')
Prepared By McGregor GeoScience Ltd.
Halifax, Nova Scotia

FIGURE 11

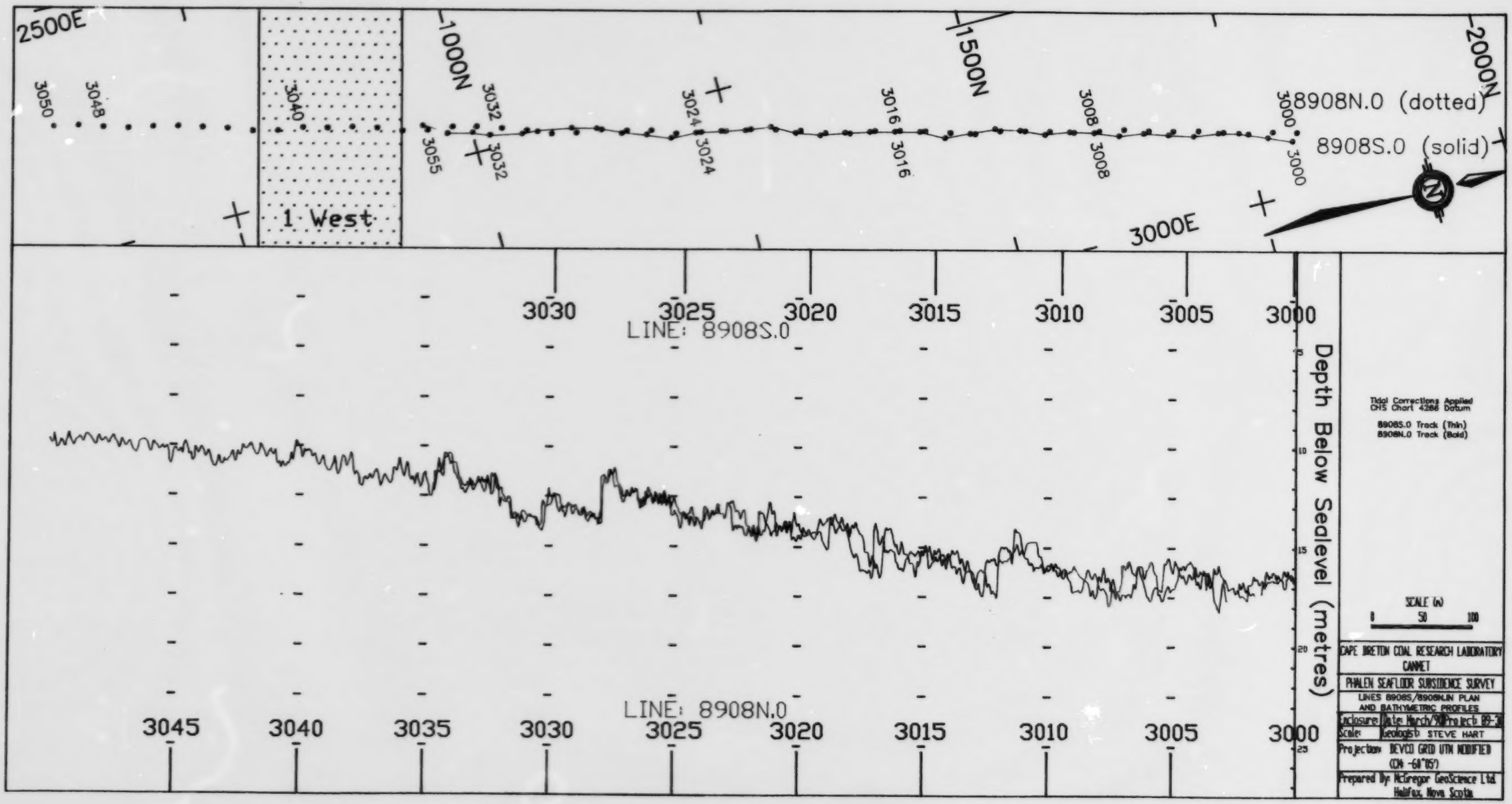

2500E
1000N
1500N
2000N
3000E
1 West
3050
3048
3040
3055
3032
3024
3016
3008
3000
8908N.0 (dotted)
8908S.0 (solid)
N
3030
3025
3020
3015
3010
3005
3000
LINE: 8908S.0
Depth Below Sealevel (metres)
Tidal Corrections Applied
CHS Chart 4286 Datum
8908S.0 Track (Thin)
8908N.0 Track (Bold)
SCALE (m)
0 50 100
CAPE BRETON COAL RESEARCH LABORATORY
CANMET
PHALEN SEAFLOOR SUBSIDENCE SURVEY
LINES 8908S/8908N.IN PLAN
AND BATHYMETRIC PROFILES
Enclosure
Date: March/98
Project: 89-3
Scale:
Geologist: STEVE HART
Projection: DEVCO GRID UTM MODIFIED
(CM: -60°05')
Prepared by: McGregor GeoScience Ltd.
Halifax, Nova Scotia
LINE: 8908N.0
3045
3040
3035
3030
3025
3020
3015
3010
3005
3000

FIGURE 12

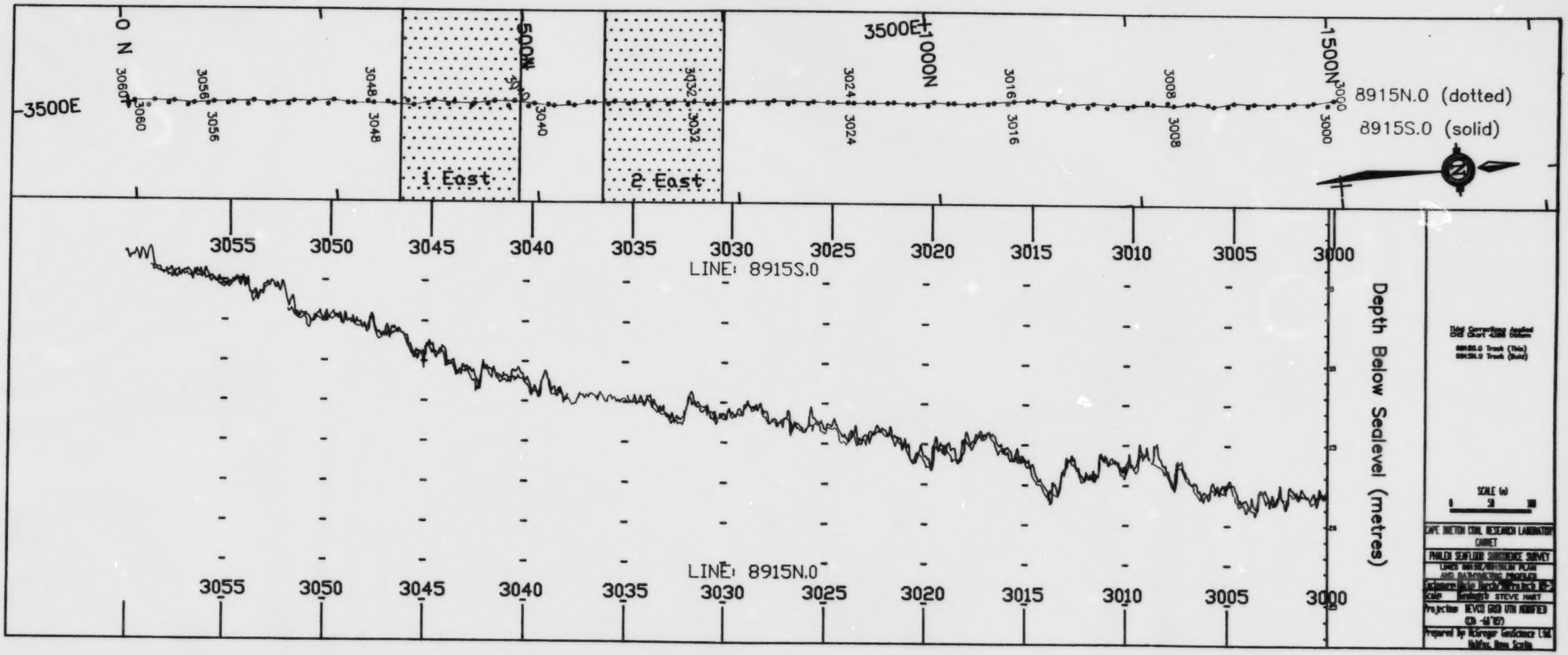

3500E
0 N
3060
3056
3048
500W
3040
1 East
3032
2 East
3500E
1000N
3024
3016
3008
1500N
3000
8915N.0 (dotted)
8915S.0 (solid)
3055
3050
3045
3040
3035
3030
3025
3020
3015
3010
3005
3000
LINE: 8915S.0
LINE: 8915N.0
Depth Below Sealevel (metres)
SCALE (m)
CAPE BRETON COAL RESEARCH LABORATORY
CANMET
PARLEE SEAFLOOR SUBSIDENCE SURVEY
Geologist: STEVE HART

FIGURE 13

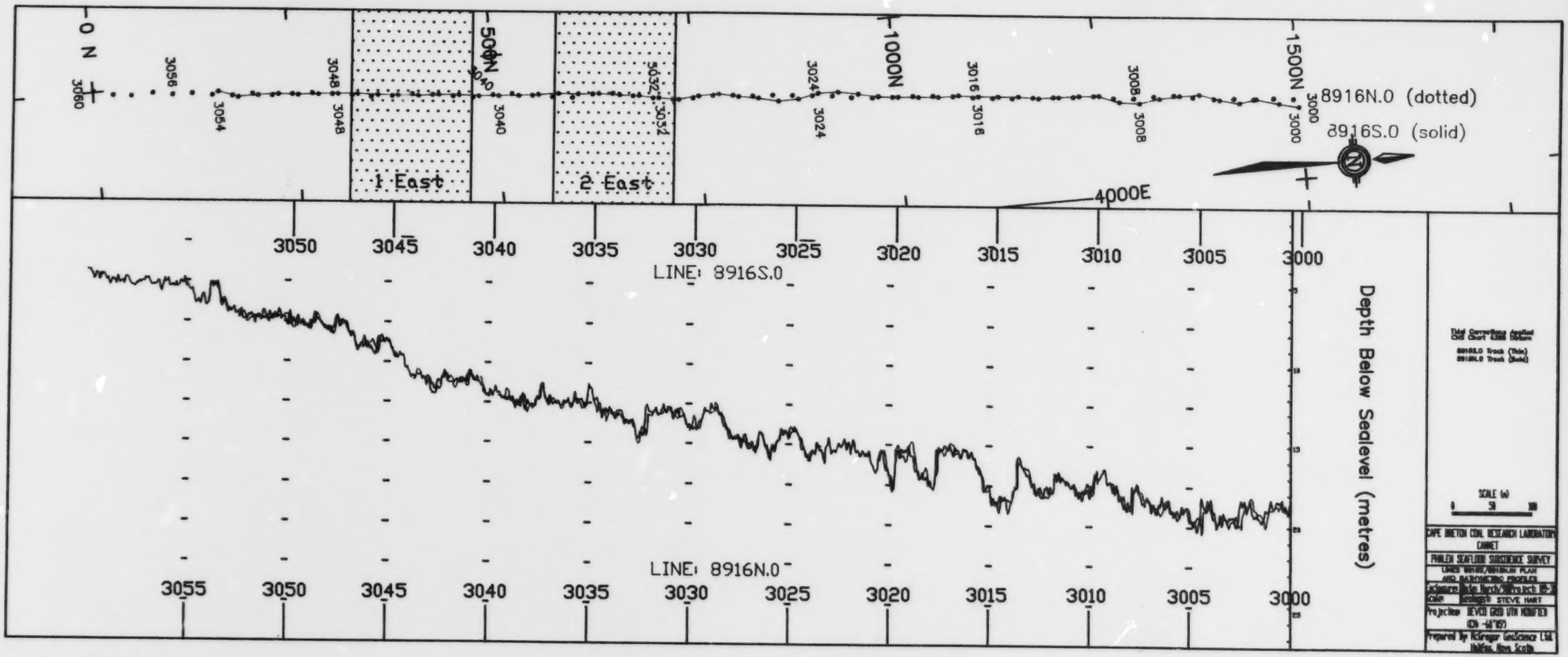

0 N
500N
1000N
1500N
8916N.0 (dotted)
8916S.0 (solid)
1 East
2 East
4000E
3060
3056
3054
3048
3048
3040
3040
3032
3032
3024
3024
3016
3016
3008
3008
3000
3000
3050
3045
3040
3035
3030
3025
3020
3015
3010
3005
3000
LINE: 8916S.0
LINE: 8916N.0
3055
3050
3045
3040
3035
3030
3025
3020
3015
3010
3005
3000
Depth Below Sealevel (metres)
SCALE (m)
CAPE BRETON COAL RESEARCH LABORATORY
CANMET
PHALEN SEAFLOOR SUBSIDENCE SURVEY
Projection: REVISED GRID UTM NORTH
Prepared by McGregor GeoScience Ltd.
Halifax, Nova Scotia

FIGURE 14

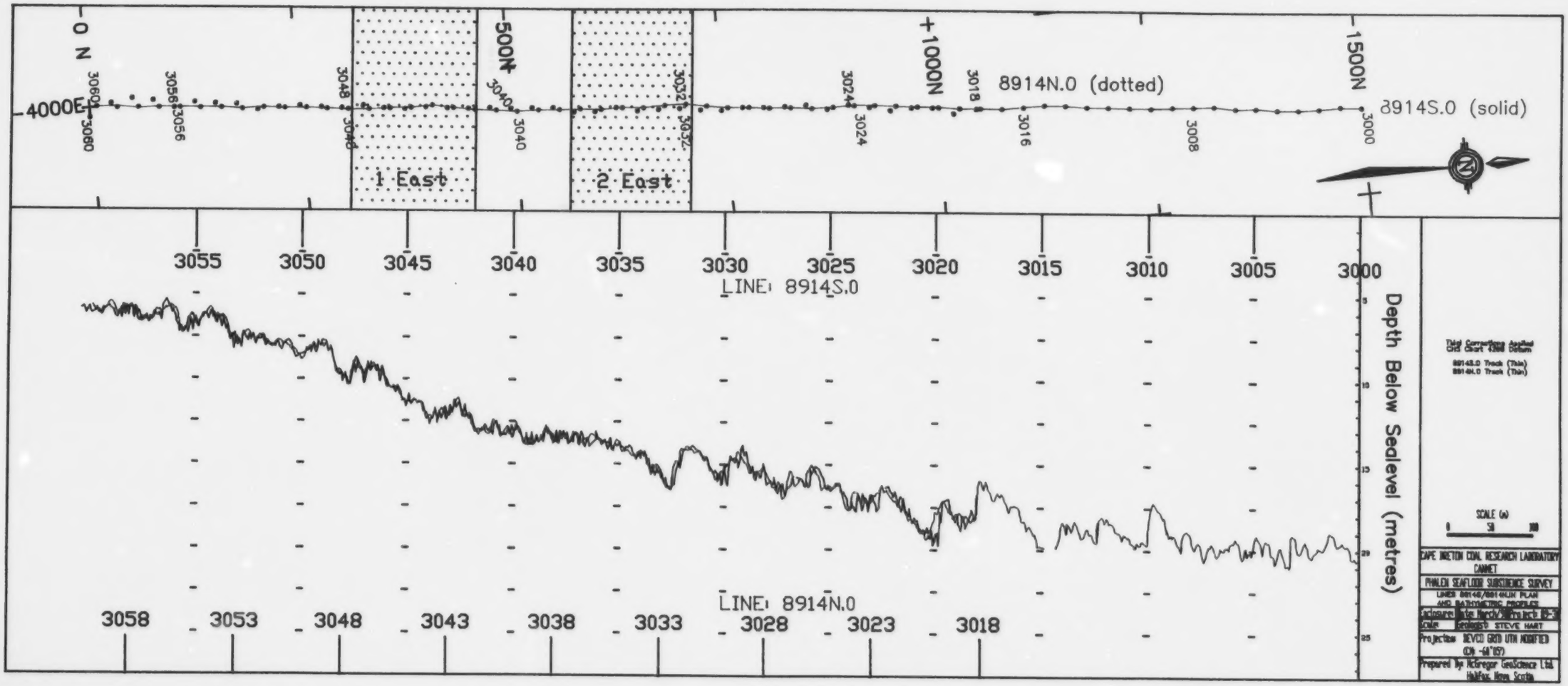

0 N
4000E
500N
1000N
1500N
8914N.0 (dotted)
8914S.0 (solid)
1 East
2 East
LINE: 8914S.0
LINE: 8914N.0
Depth Below Sealevel (metres)
CAPE BRETON COAL RESEARCH LABORATORY
CANMET
PHALEN SEAFLOOR SUBSIDENCE SURVEY
Projection NEVCO GRID UTM MODIFIED
Prepared by McGregor GeoScience Ltd.
Halifax, Nova Scotia

FIGURE 15

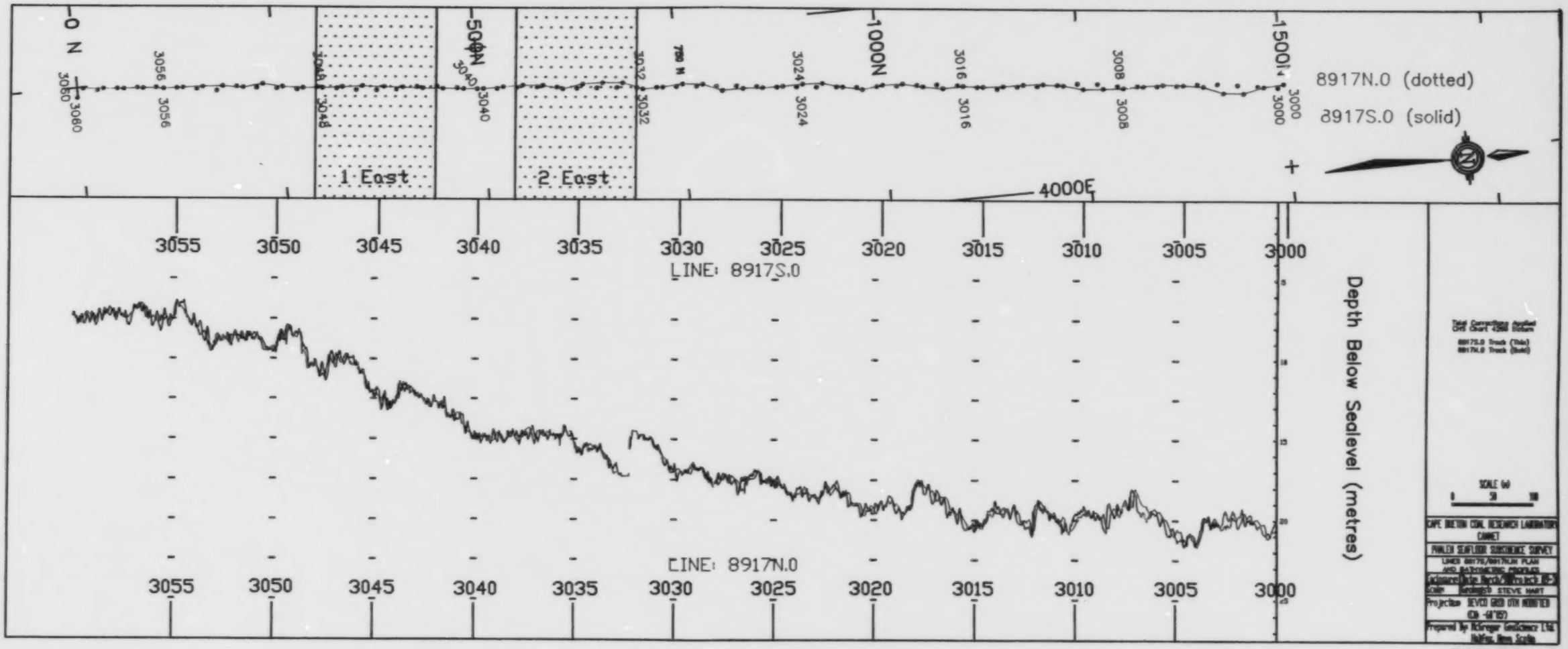

0 N
500N
1000N
1500N
3056
3048
3040
3032
3024
3016
3008
3000
1 East
2 East
4000E
8917N.0 (dotted)
8917S.0 (solid)
3055
3050
3045
3040
3035
3030
3025
3020
3015
3010
3005
3000
LINE: 8917S.0
LINE: 8917N.0
Depth Below Sealevel (metres)

FIGURE 16

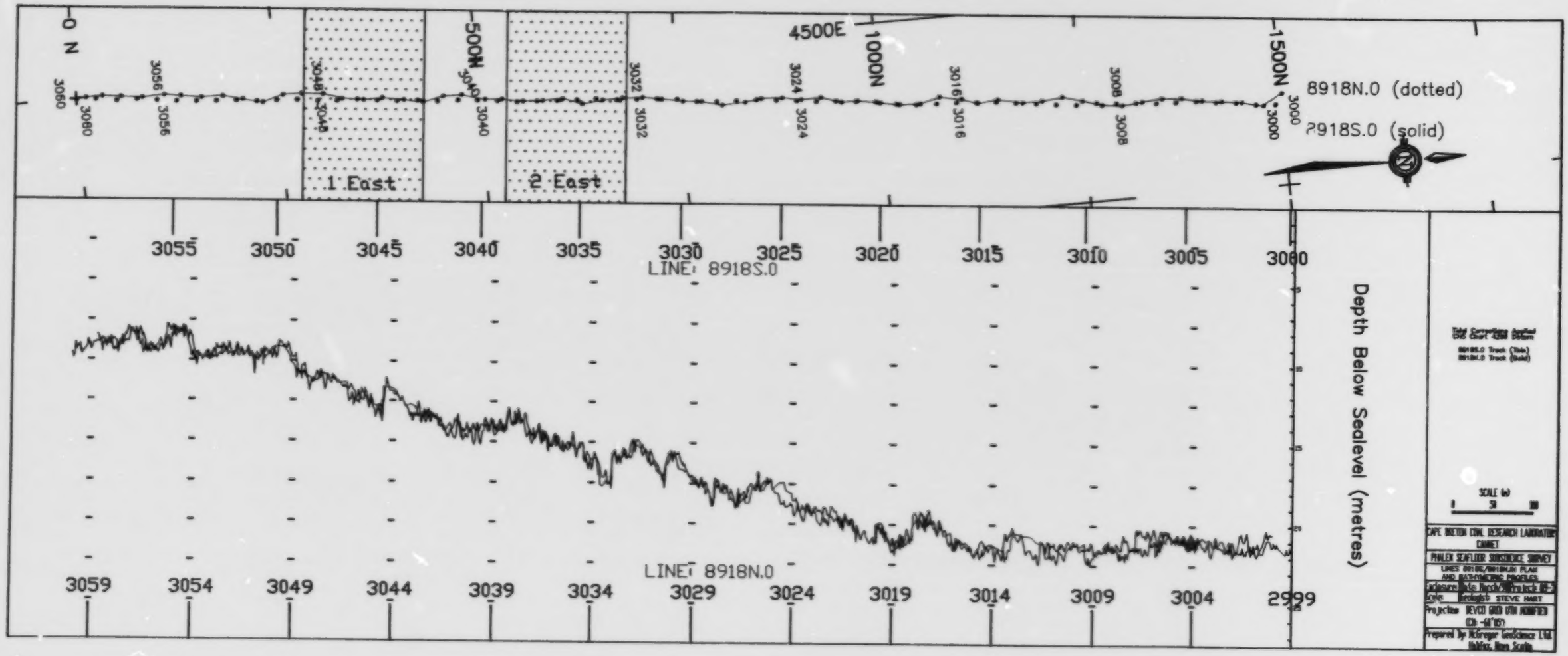

0 N
500N
1000N
1500N
4500E
1 East
2 East
8918N.0 (dotted)
8918S.0 (solid)
LINE: 8918S.0
LINE: 8918N.0
Depth Below Sealevel (metres)
3055
3050
3045
3040
3035
3030
3025
3020
3015
3010
3005
3000
3059
3054
3049
3044
3039
3034
3029
3024
3019
3014
3009
3004
2999

FIGURE 17

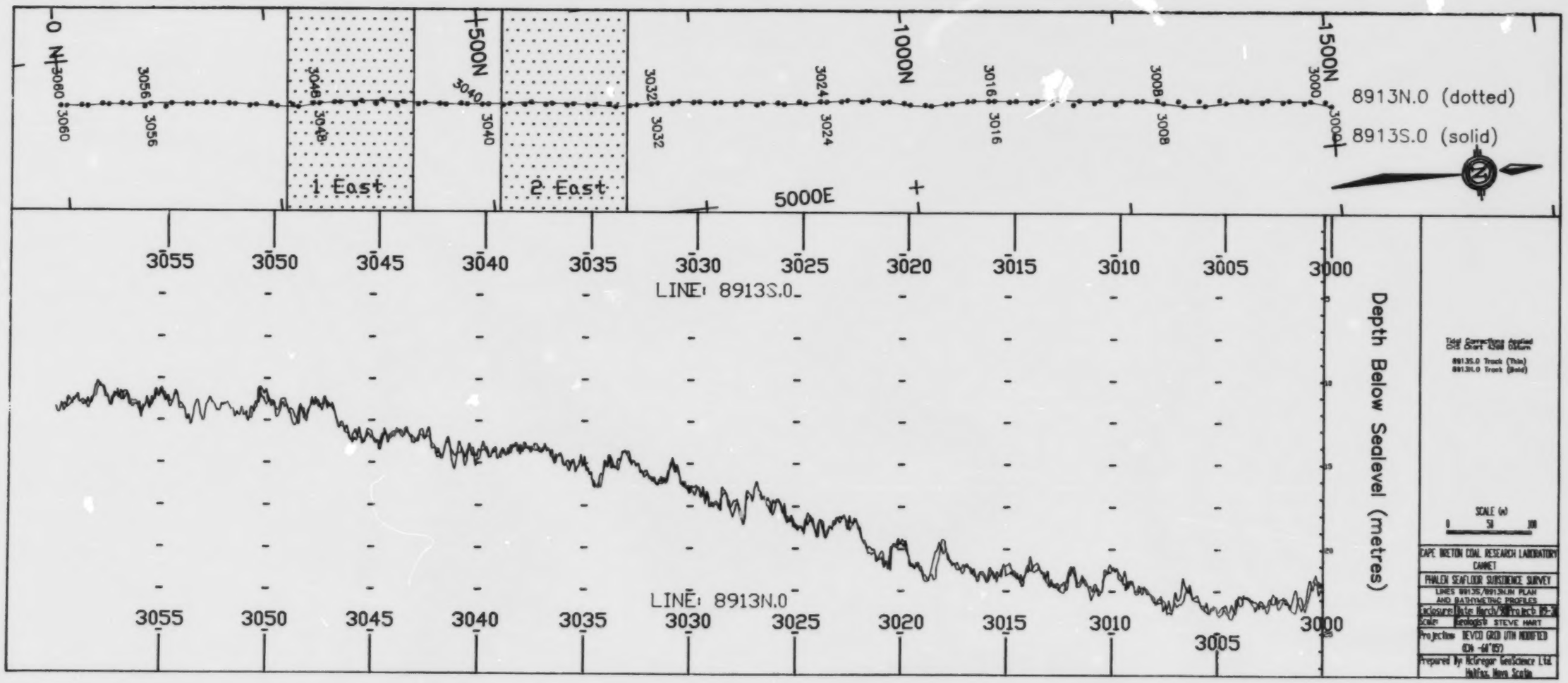

0 N
500N
1000N
1500N
3060
3056
3048
3040
3032
3024
3016
3008
3000
8913N.0 (dotted)
8913S.0 (solid)
1 East
2 East
5000E
3055
3050
3045
3040
3035
3030
3025
3020
3015
3010
3005
3000
LINE: 8913S.0
LINE: 8913N.0
Depth Below Sealevel (metres)
Total Corrections Applied
CHS Chart Datum
8913S.0 Track (Thin)
8913N.0 Track (Bold)
SCALE (m)
0
50
100
CAPE BRETON COAL RESEARCH LABORATORY
CANMET
PHALEN SEAFLOOR SUBSIDENCE SURVEY
LINES 8913S/8913N.IN PLAN
AND BATHYMETRIC PROFILES
Enclosure
Scale
Geologist STEVE HART
Projection
Prepared By McGregor GeoScience Ltd.
Halifax, Nova Scotia

FIGURE 18

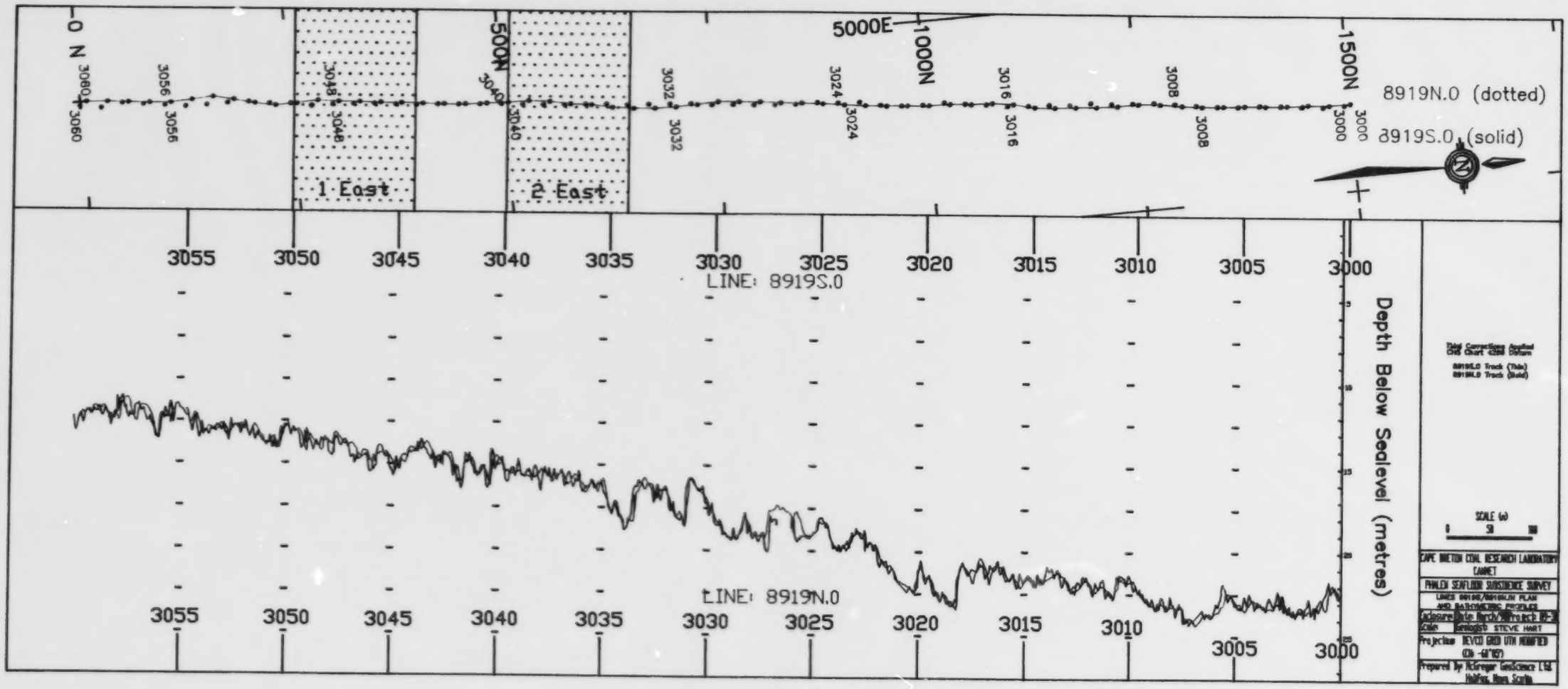

0 N
500N
1000N
1500N
5000E
1 East
2 East
8919N.0 (dotted)
8919S.0 (solid)
LINE: 8919S.0
LINE: 8919N.0
3055
3050
3045
3040
3035
3030
3025
3020
3015
3010
3005
3000
Depth Below Sealevel (metres)
SCALE (m)
CAPE BRETON COAL RESEARCH LABORATORY
CANMET
PANUKE SEAFLOOR SUBSIDENCE SURVEY
Prepared by McGregor GeoScience Ltd.
Halifax, Nova Scotia

FIGURE 19

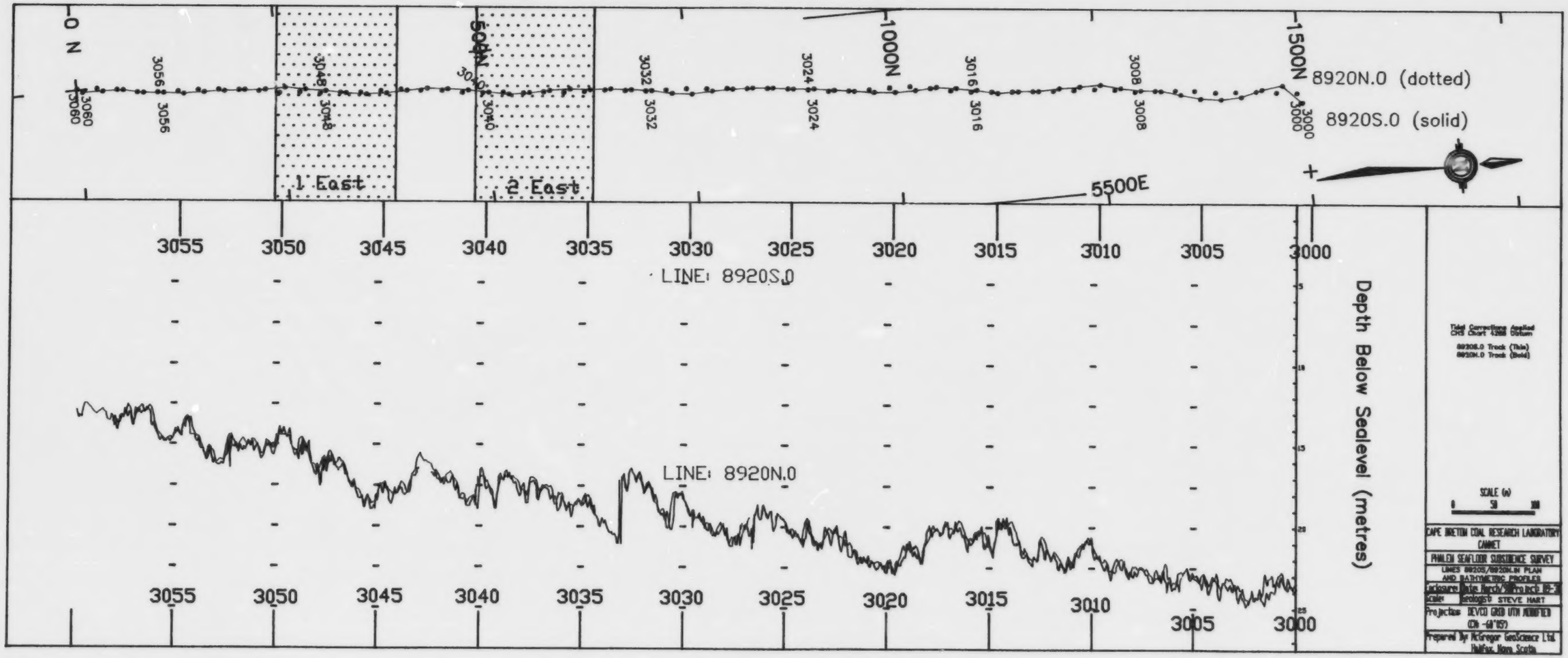

0 N
1000N
1500N
8920N.0 (dotted)
8920S.0 (solid)
1 East
2 East
5500E
3055
3050
3045
3040
3035
3030
3025
3020
3015
3010
3005
3000
LINE: 8920S.0
LINE: 8920N.0
Depth Below Sealevel (metres)
SCALE (m)
CAPE BRETON COAL RESEARCH LABORATORY
CANMET
PHALEN SEAFLOOR SUBSIDENCE SURVEY
LINES 8920S/8920N.IN PLAN
AND BATHYMETRIC PROFILES
Geologist STEVE HART
Prepared by McGregor GeoScience Ltd.
Halifax, Nova Scotia

FIGURE 20

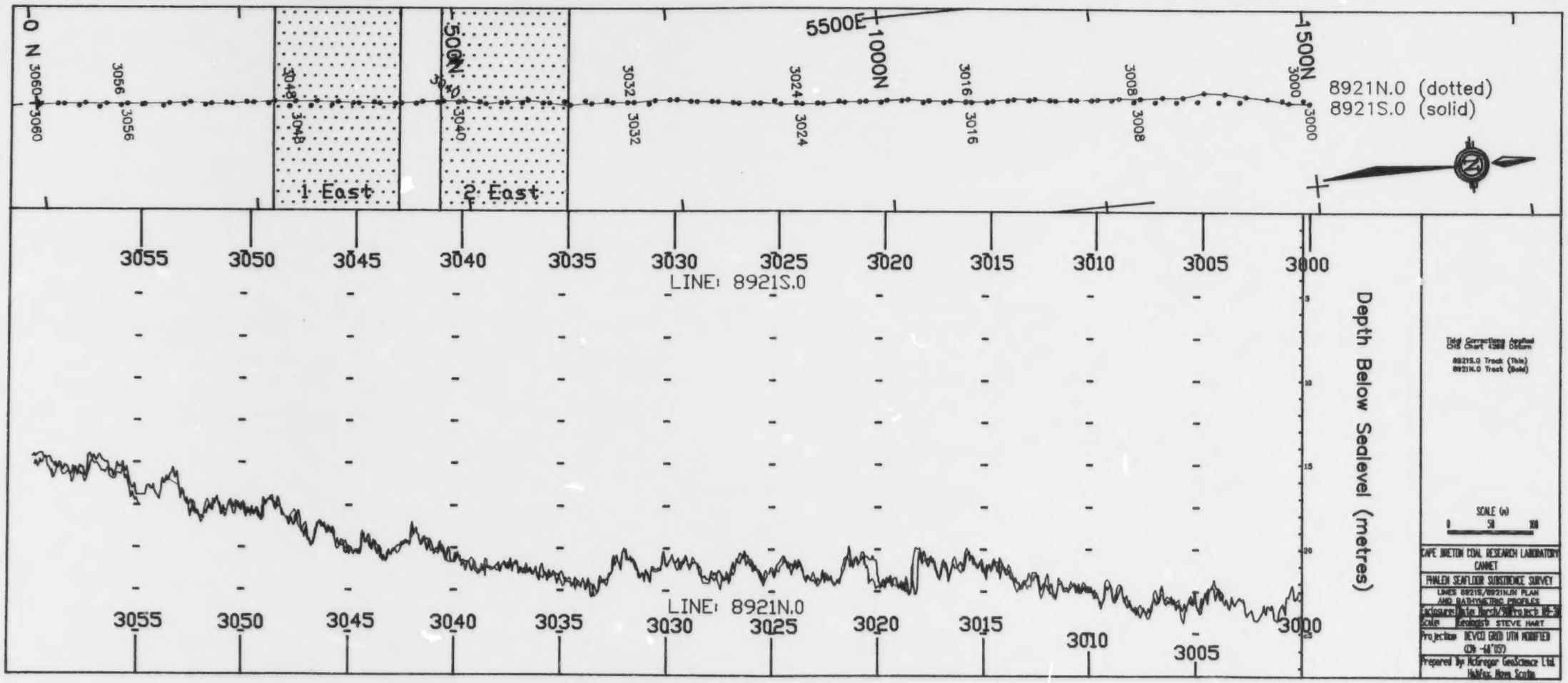

0 N
3060
3056
3048
3040
50GN
3032
3024
5500E
1000N
3016
3008
1500N
3000
8921N.0 (dotted)
8921S.0 (solid)
1 East
2 East
3055
3050
3045
3040
3035
3030
3025
3020
3015
3010
3005
3000
LINE: 8921S.0
LINE: 8921N.0
Depth Below Sealevel (metres)
Tidal Corrections Applied
CHS Chart 4388 Datum
8921S.0 Track (Thin)
8921N.0 Track (Dash)
SCALE (m)
0
50
100
CAPE BRETON CIVIL RESEARCH LABORATORY
CANMET
PHALEN SEAFLOOR SUBSIDENCE SURVEY
LINES 8921S/8921N.M PLAN
AND BATHYMETRIC PROFILES
Reference
Scale
Geologist: STEVE HART
Projection REVCO GRID UTM MODIFIED
(CM -60°00')
Prepared by McGregor GeoScience Ltd.
Halifax, Nova Scotia

FIGURE 21

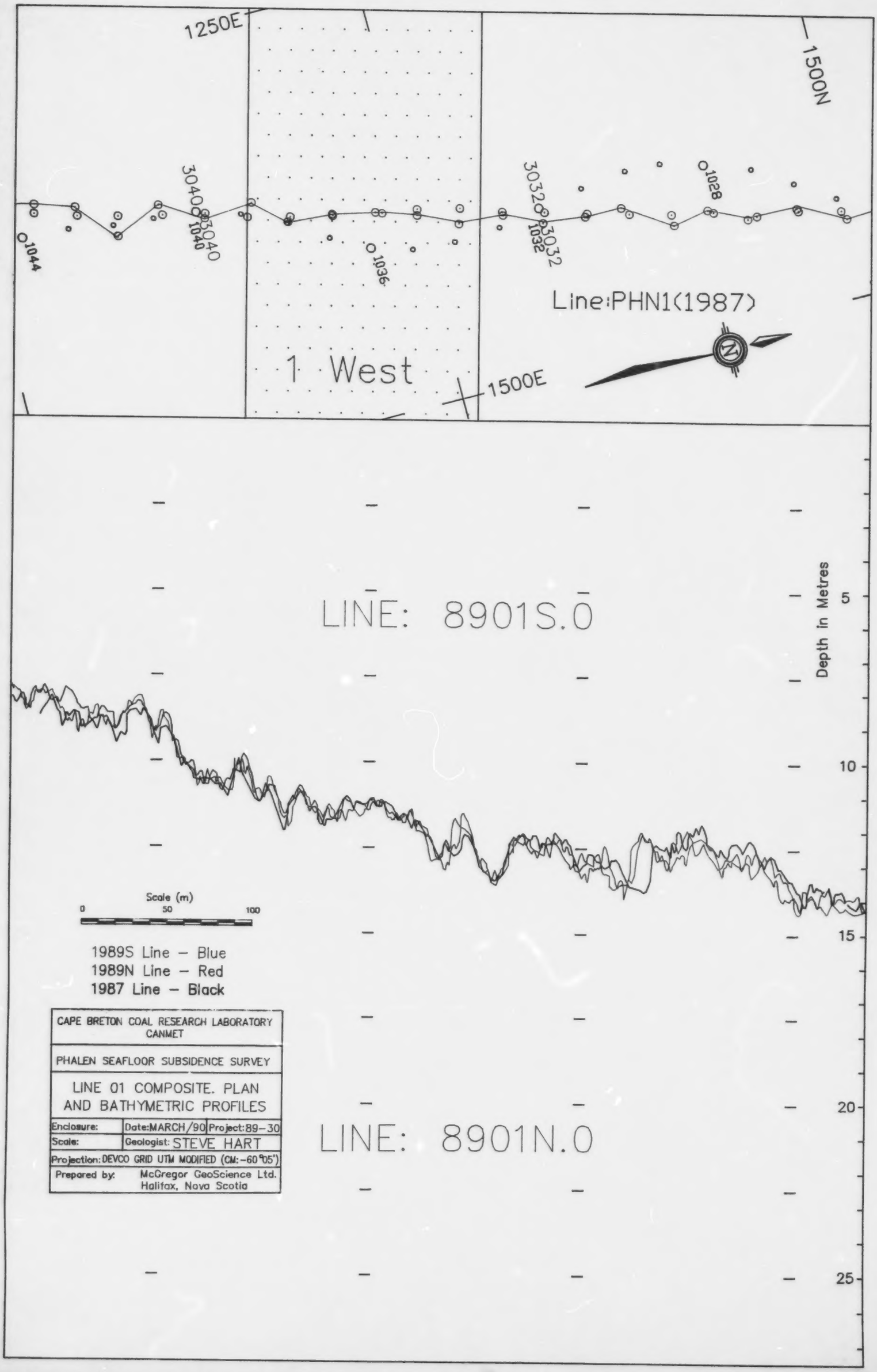
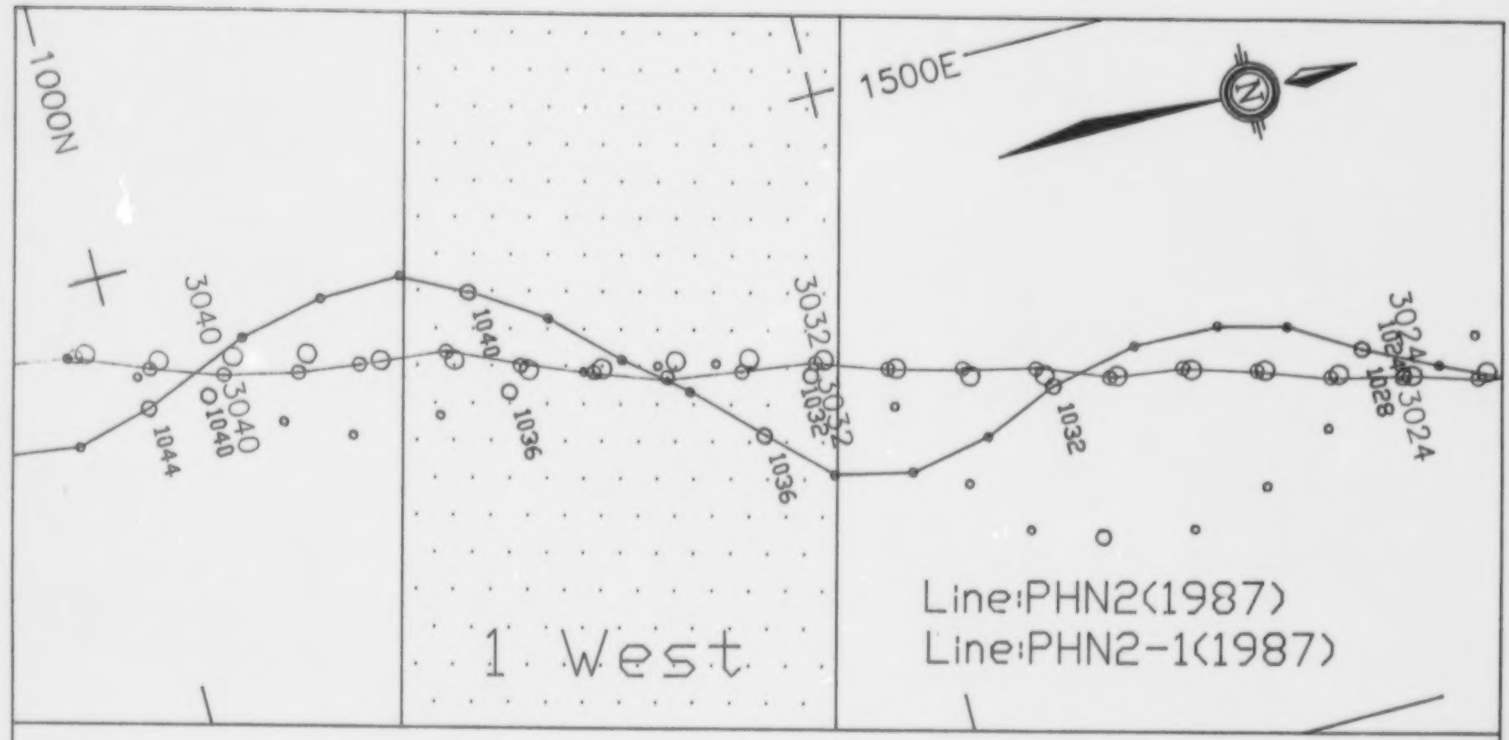
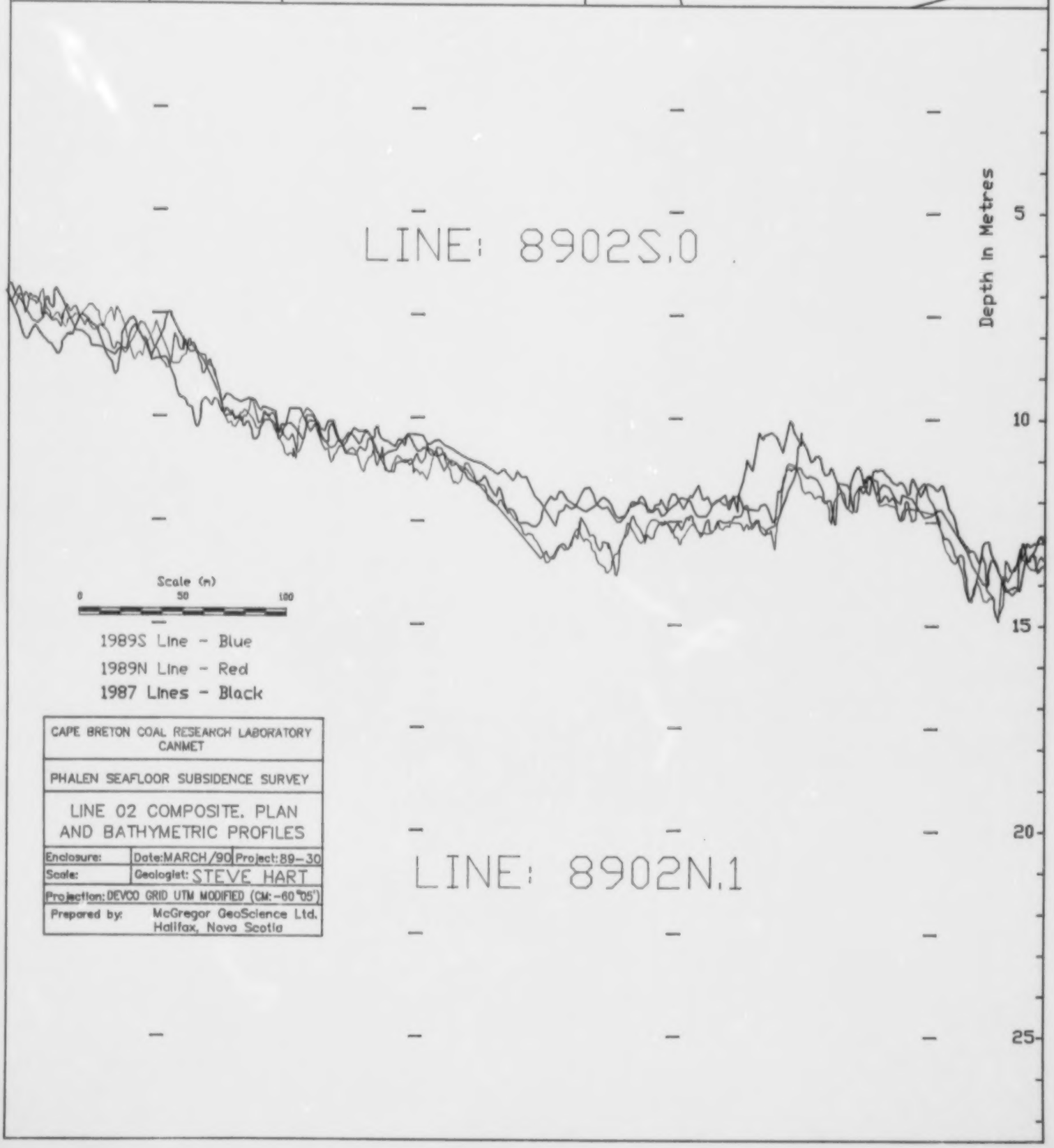

1250E
1500N
1500E
1 West
3040
3040
1040
1044
1036
3032
3032
1032
1028
Line:PHN1(1987)
N
LINE: 8901S.0
LINE: 8901N.0
Depth in Metres
5
10
15
20
25
Scale (m)
0
50
100
1989S Line – Blue
1989N Line – Red
1987 Line – Black
CAPE BRETON COAL RESEARCH LABORATORY
CANMET
PHALEN SEAFLOOR SUBSIDENCE SURVEY
LINE 01 COMPOSITE. PLAN
AND BATHYMETRIC PROFILES
Enclosure:
Date:MARCH/90
Project:89-30
Scale:
Geologist: STEVE HART
Projection: DEVCO GRID UTM MODIFIED (CM:-60°05')
Prepared by:
McGregor GeoScience Ltd.
Halifax, Nova Scotia

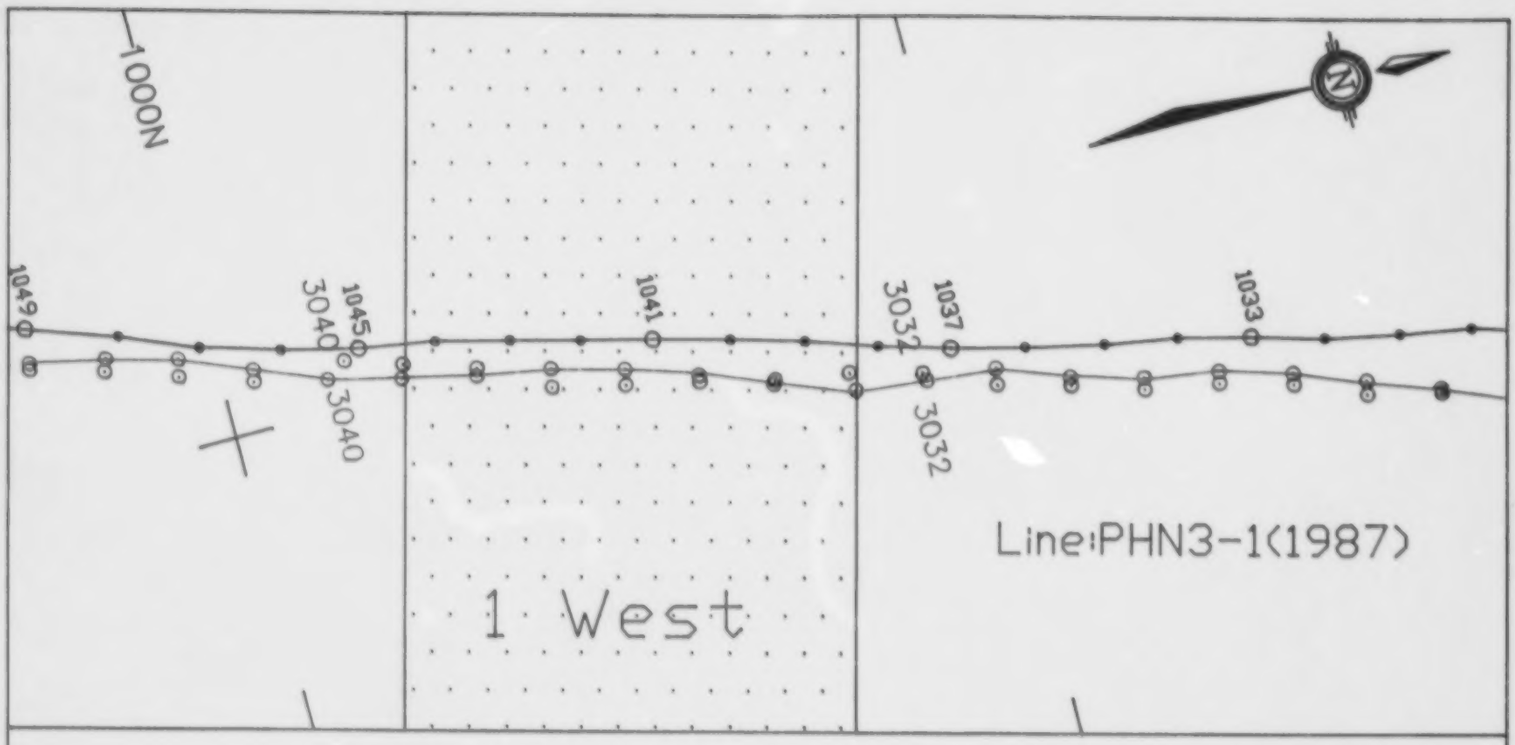
FIGURE 22

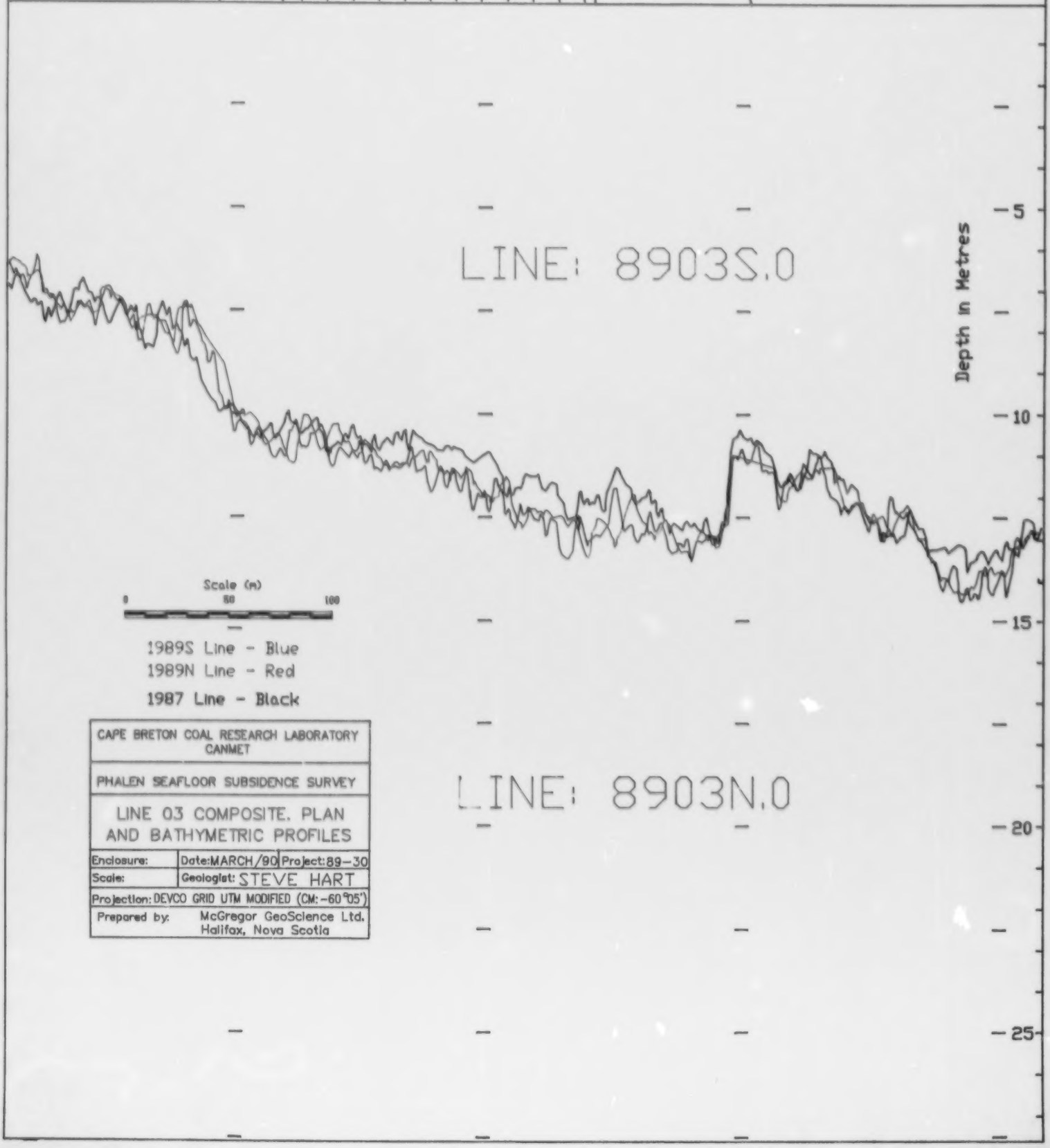




CAPE BRETON COAL RESEARCH LABORATORY CANMET	
PHALEN SEAFLOOR SUBSIDENCE SURVEY	
LINE 02 COMPOSITE. PLAN AND BATHYMETRIC PROFILES	
Enclosure:	Date:MARCH/90 Project:89-30
Scale:	Geologist: STEVE HART
Projection: DEVCO GRID UTM MODIFIED (CM:-60°05')	
Prepared by:	McGregor GeoScience Ltd. Halifax, Nova Scotia

FIGURE 23





CAPE BRETON COAL RESEARCH LABORATORY CANMET	
PHALEN SEAFLOOR SUBSIDENCE SURVEY	
LINE 03 COMPOSITE. PLAN AND BATHYMETRIC PROFILES	
Enclosure:	Date:MARCH/90 Project:89-30
Scale:	Geologist: STEVE HART
Projection: DEVCO GRID UTM MODIFIED (CM:-60°05')	
Prepared by:	McGregor GeoScience Ltd. Halifax, Nova Scotia

FIGURE 24

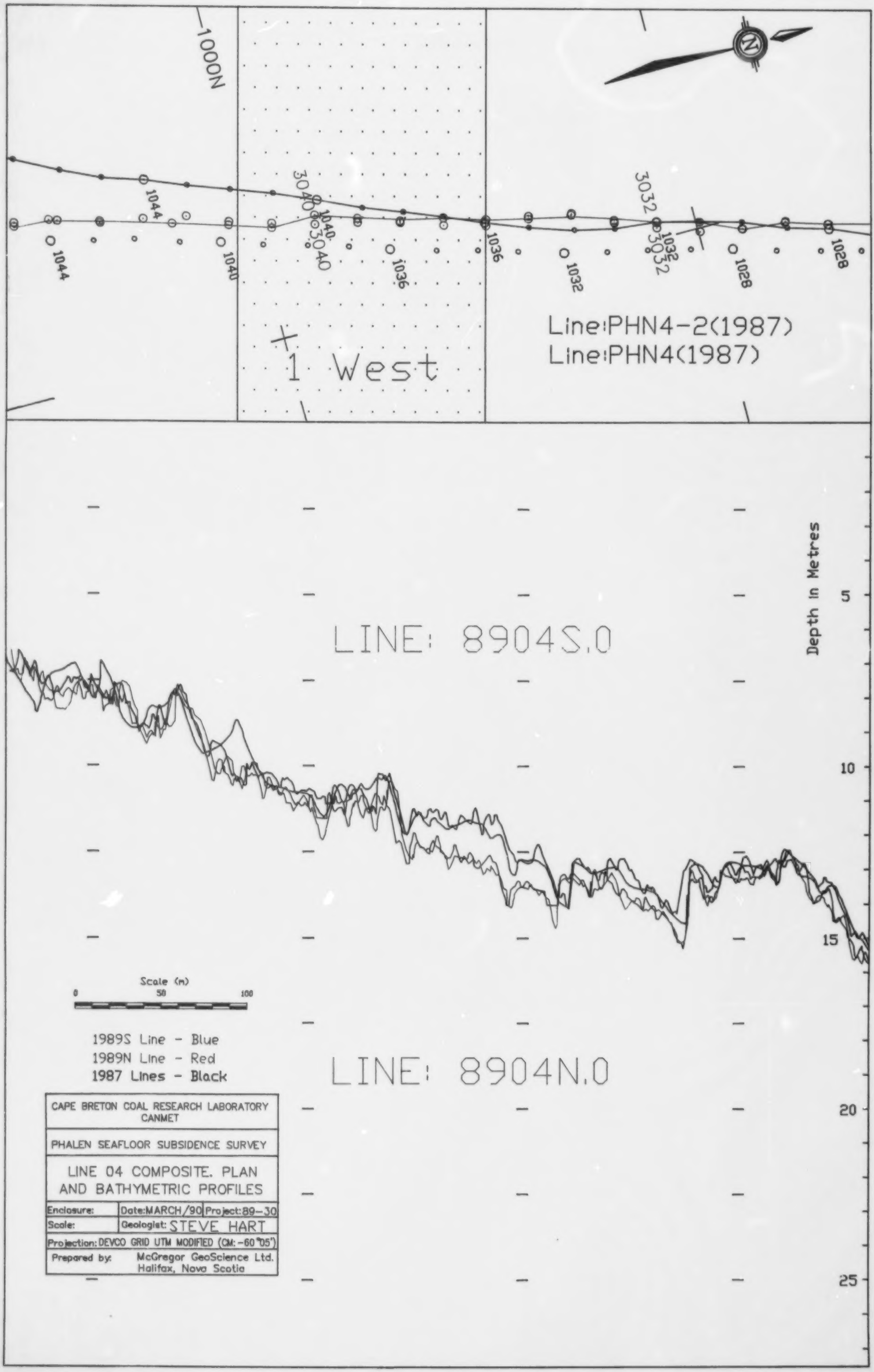
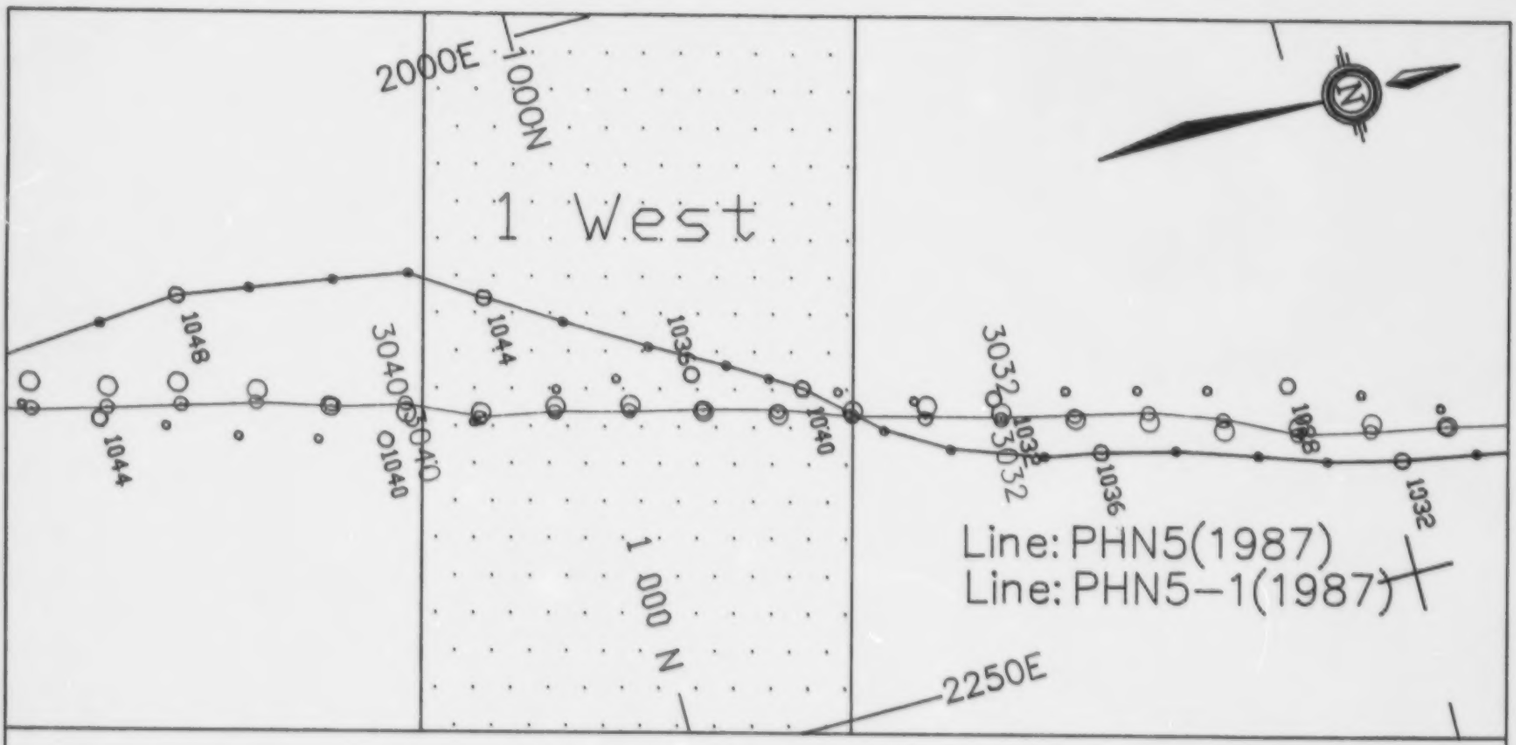
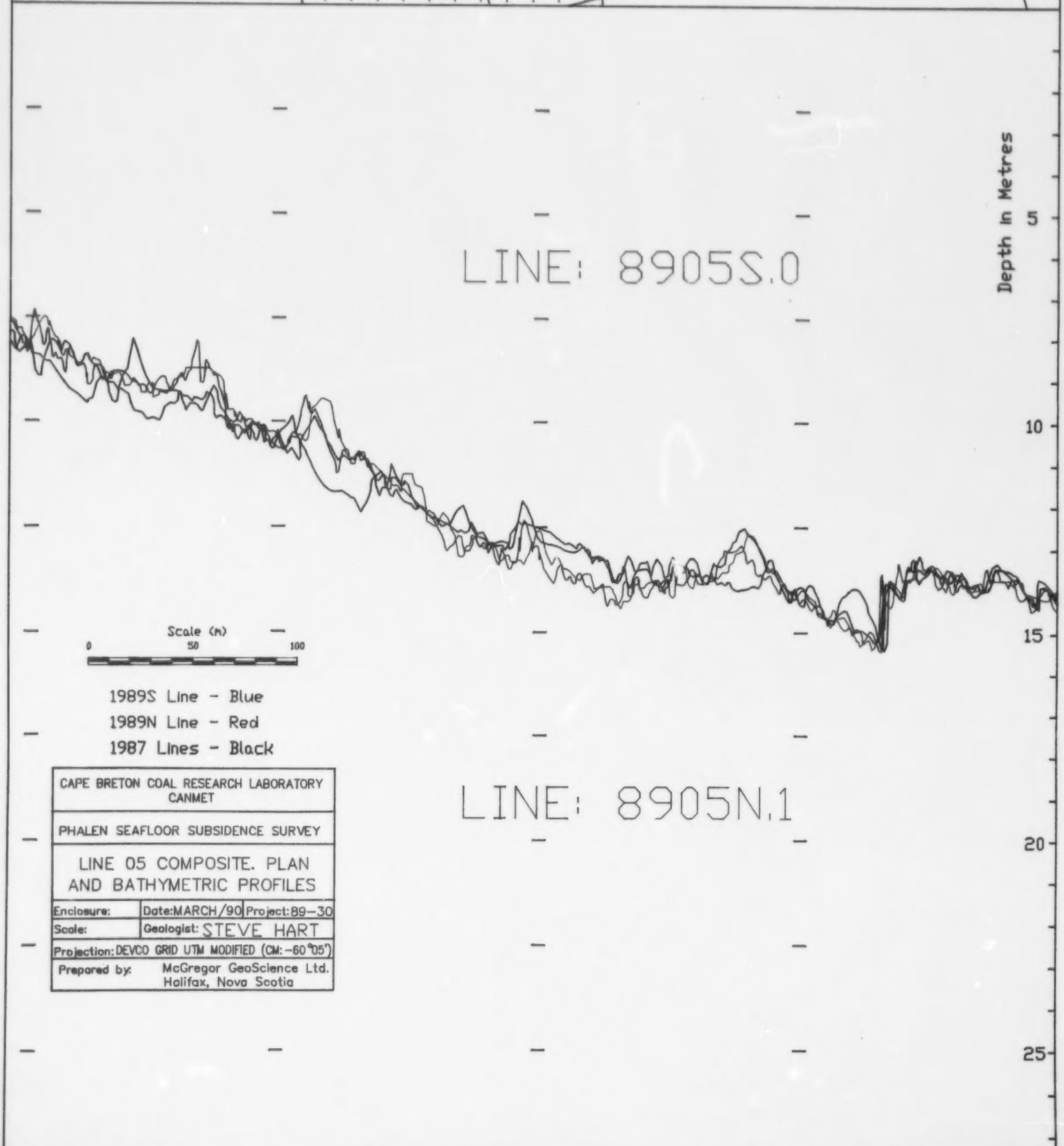

1000N
1044
1040
3040
1040
3040
1036
1036
1032
3032
1032
3032
1028
1028
Line:PHN4-2(1987)
Line:PHN4(1987)
1 West
LINE: 8904S.0
LINE: 8904N.0
Depth in Metres
5
10
15
20
25
Scale (m)
0
50
100
1989S Line - Blue
1989N Line - Red
1987 Lines - Black
CAPE BRETON COAL RESEARCH LABORATORY
CANMET
PHALEN SEAFLOOR SUBSIDENCE SURVEY
LINE 04 COMPOSITE. PLAN
AND BATHYMETRIC PROFILES
Enclosure:
Date:MARCH/90
Project:89-30
Scale:
Geologist: STEVE HART
Projection: DEVCO GRID UTM MODIFIED (CM:-60°05')
Prepared by:
McGregor GeoScience Ltd.
Halifax, Nova Scotia

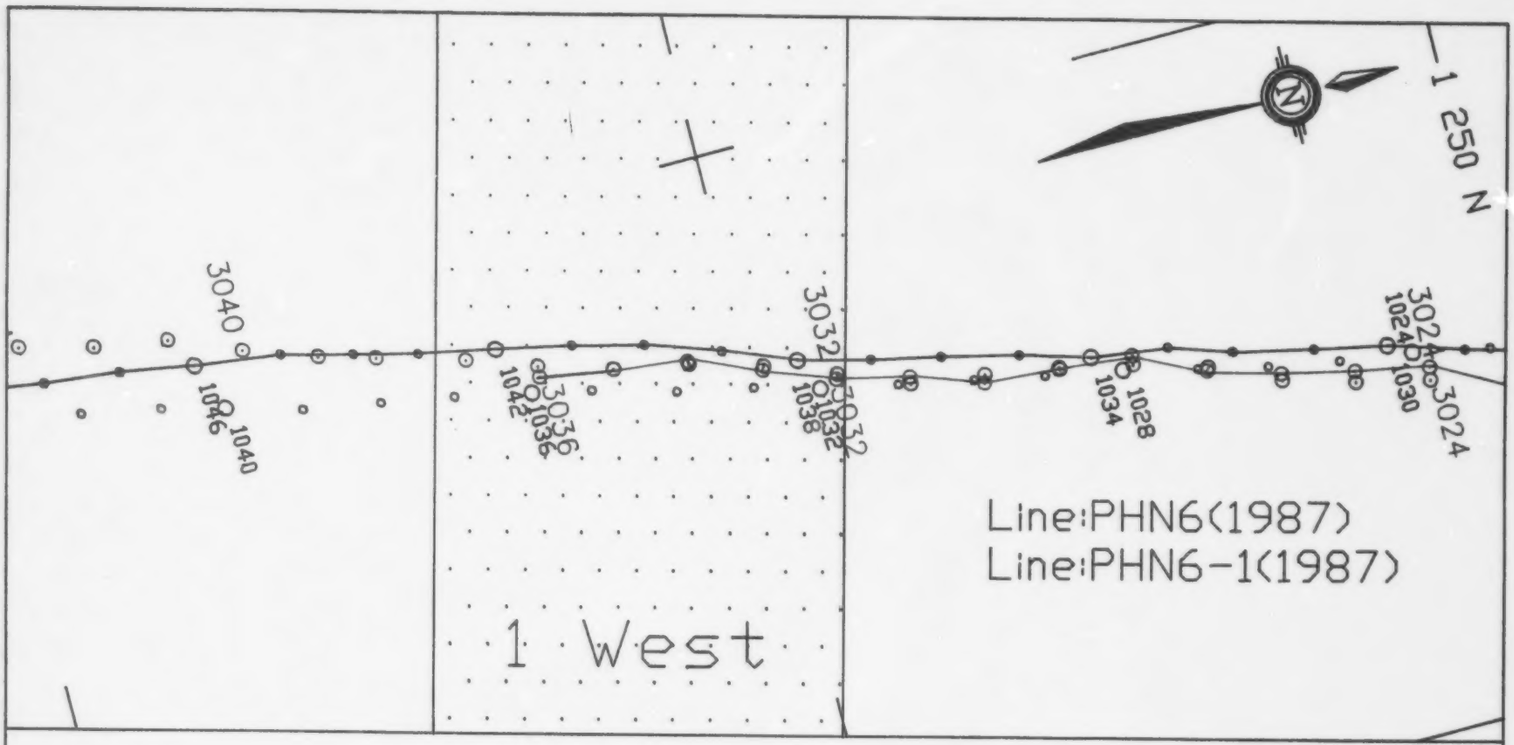
FIGURE 25

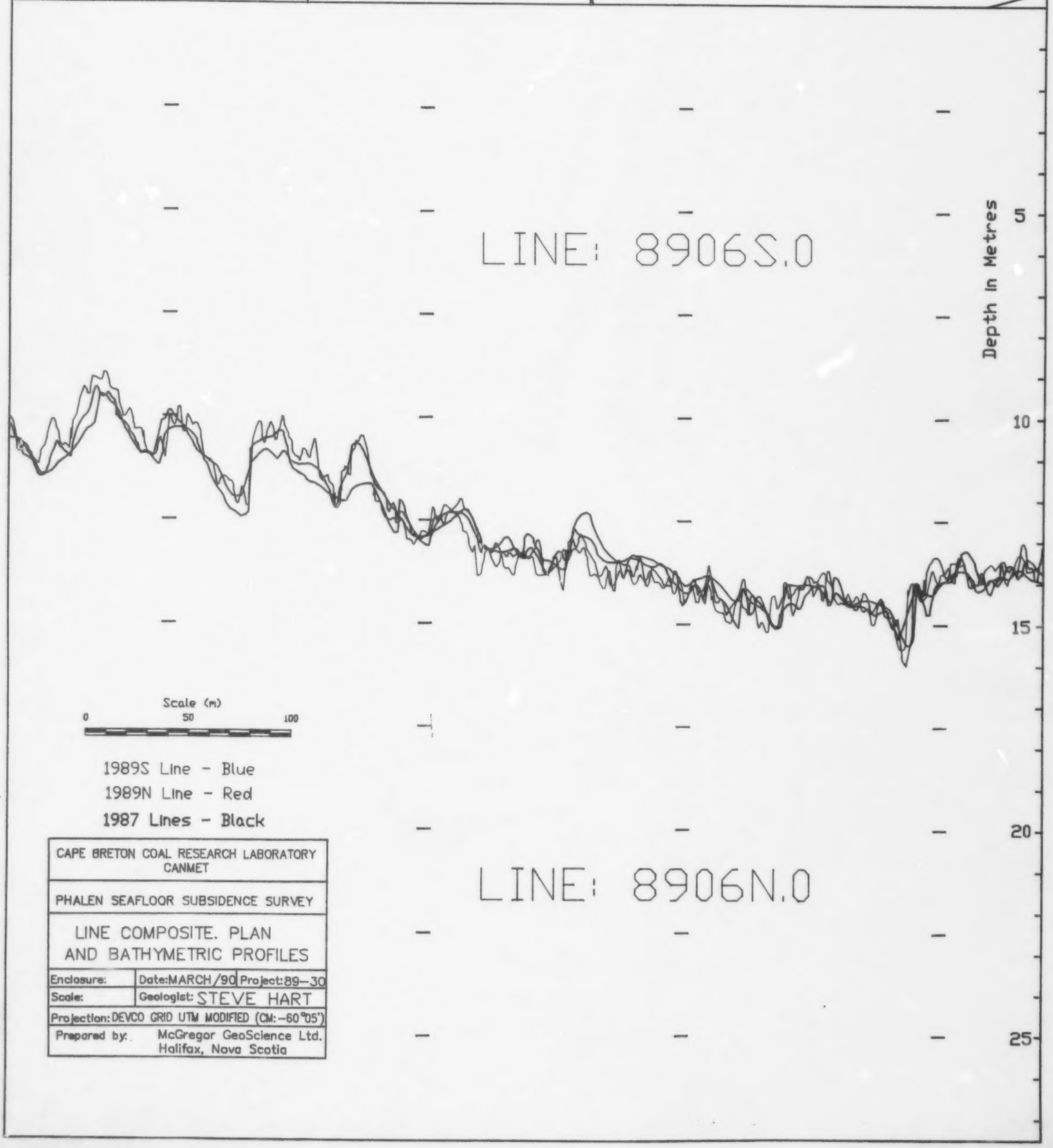




CAPE BRETON COAL RESEARCH LABORATORY CANMET		
PHALEN SEAFLOOR SUBSIDENCE SURVEY		
LINE 05 COMPOSITE. PLAN AND BATHYMETRIC PROFILES		
Enclosure:	Date: MARCH/90	Project: 89-30
Scale:	Geologist: STEVE HART	
Projection: DEVCO GRID UTM MODIFIED (CM: -60°05')		
Prepared by:	McGregor GeoScience Ltd. Halifax, Nova Scotia	

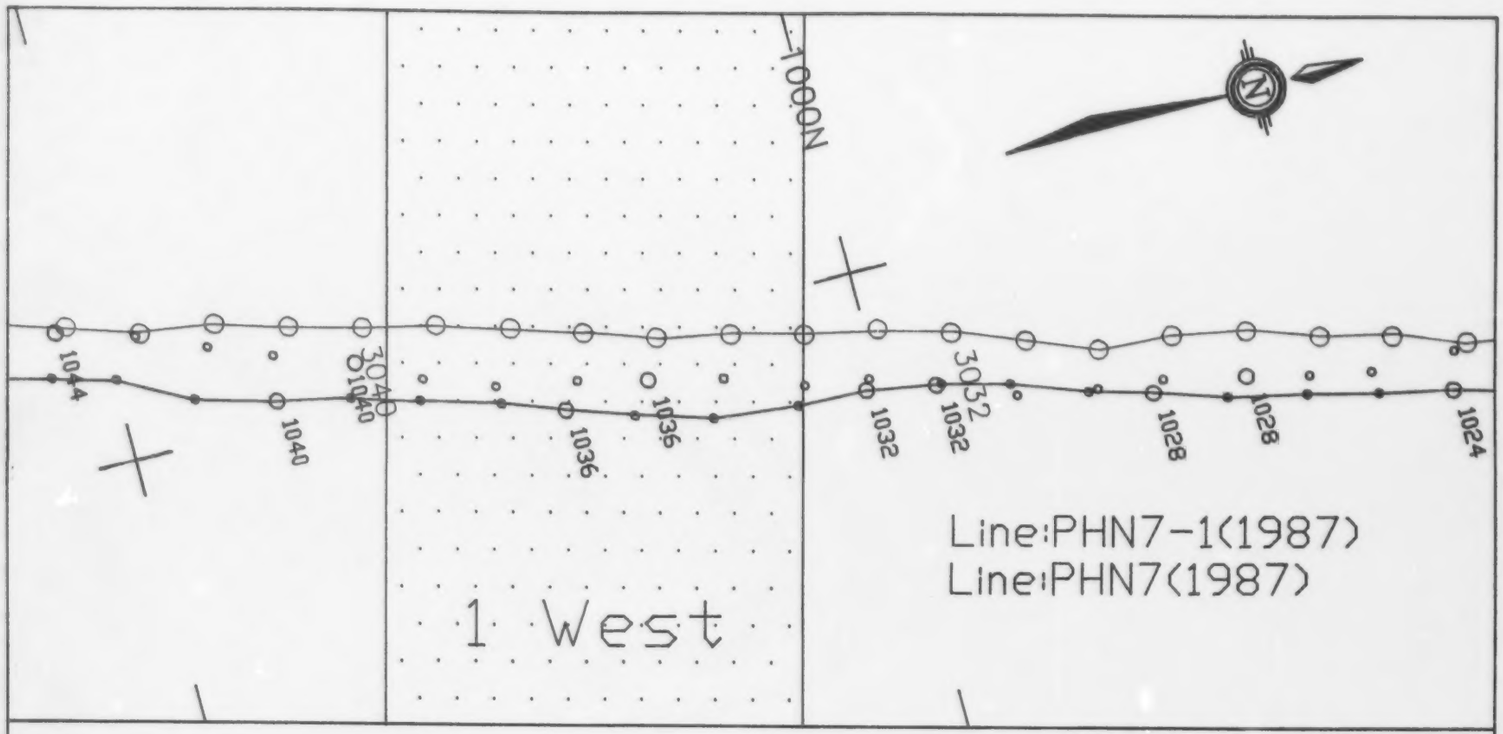
FIGURE 26

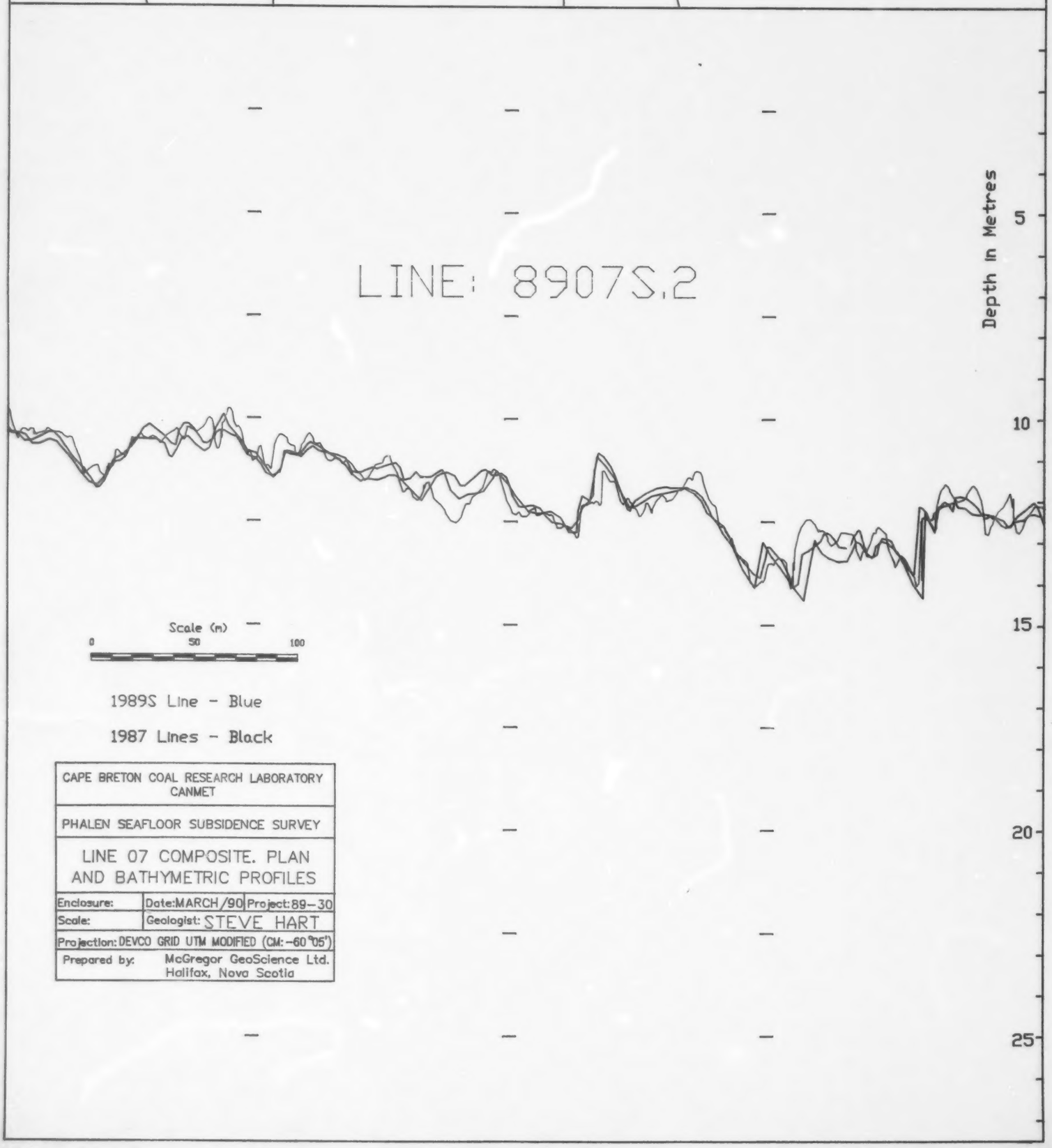




CAPE BRETON COAL RESEARCH LABORATORY CANMET		
PHALEN SEAFLOOR SUBSIDENCE SURVEY		
LINE COMPOSITE. PLAN AND BATHYMETRIC PROFILES		
Enclosure:	Date:MARCH/90	Project:89-30
Scale:	Geologist: STEVE HART	
Projection: DEVCO GRID UTM MODIFIED (CM: -60°05')		
Prepared by:	McGregor GeoScience Ltd. Halifax, Nova Scotia	

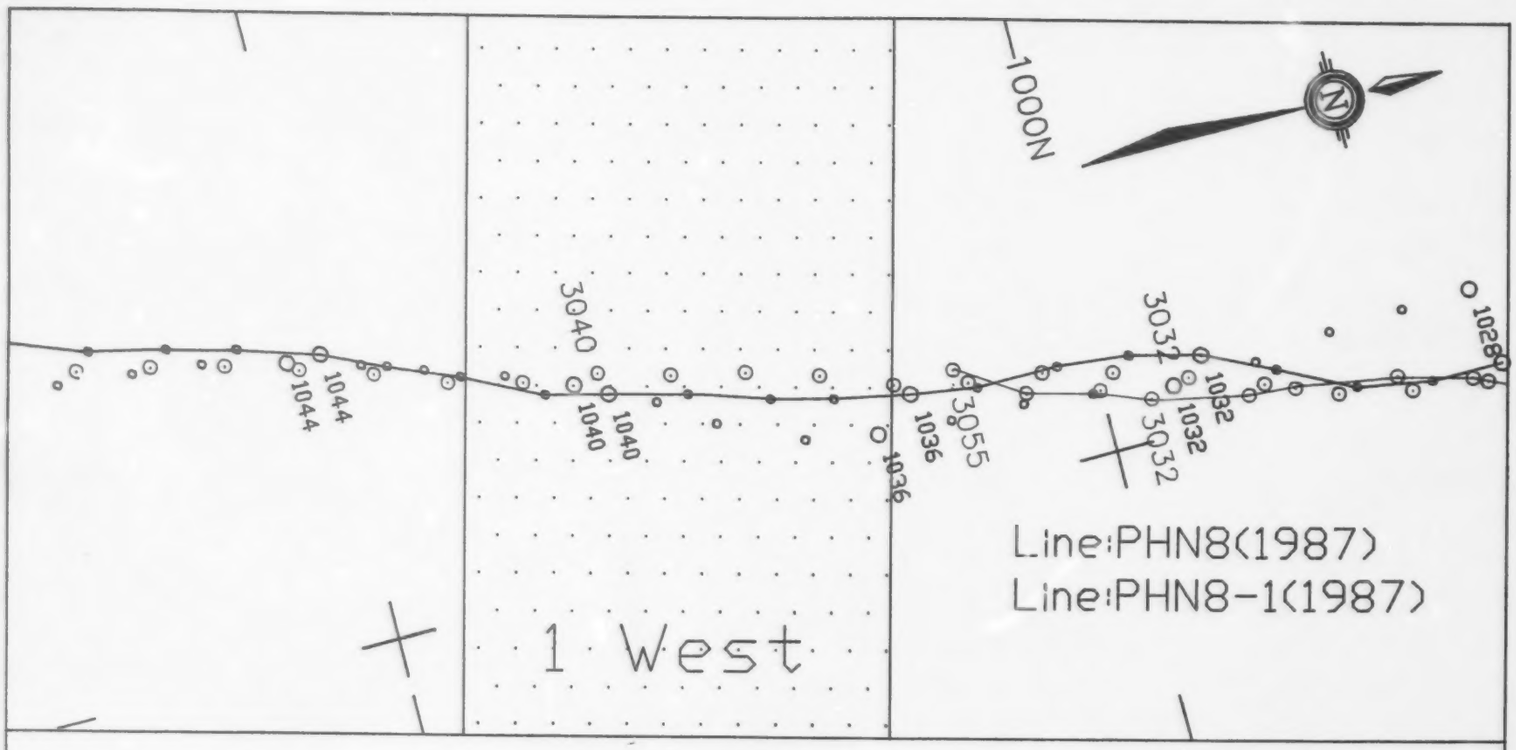
FIGURE 27

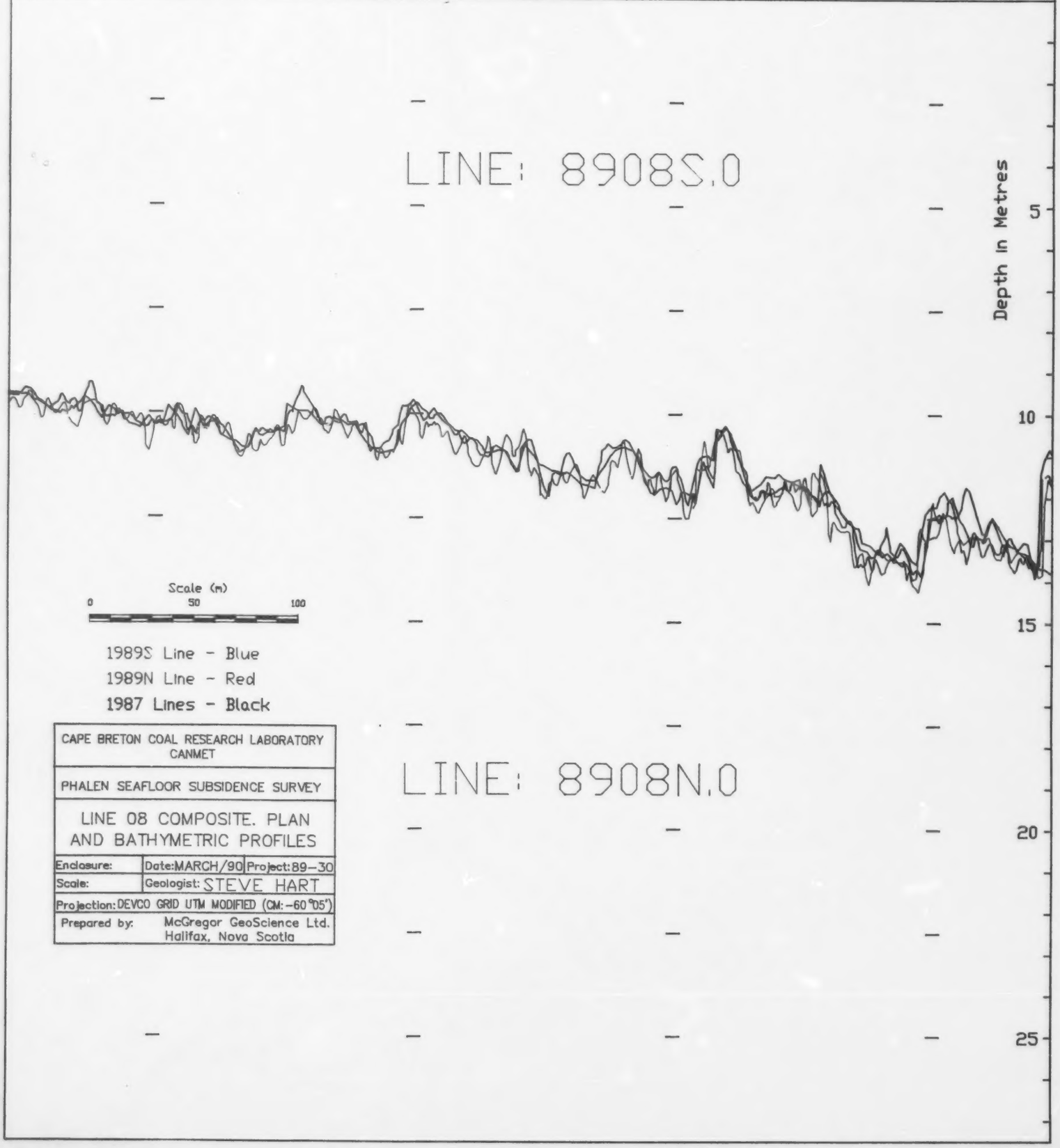




CAPE BRETON COAL RESEARCH LABORATORY CANMET		
PHALEN SEAFLOOR SUBSIDENCE SURVEY		
LINE 07 COMPOSITE. PLAN AND BATHYMETRIC PROFILES		
Enclosure:	Date: MARCH/90	Project: 89-30
Scale:	Geologist: STEVE HART	
Projection: DEVCO GRID UTM MODIFIED (CM: -60°05')		
Prepared by:	McGregor GeoScience Ltd. Halifax, Nova Scotia	

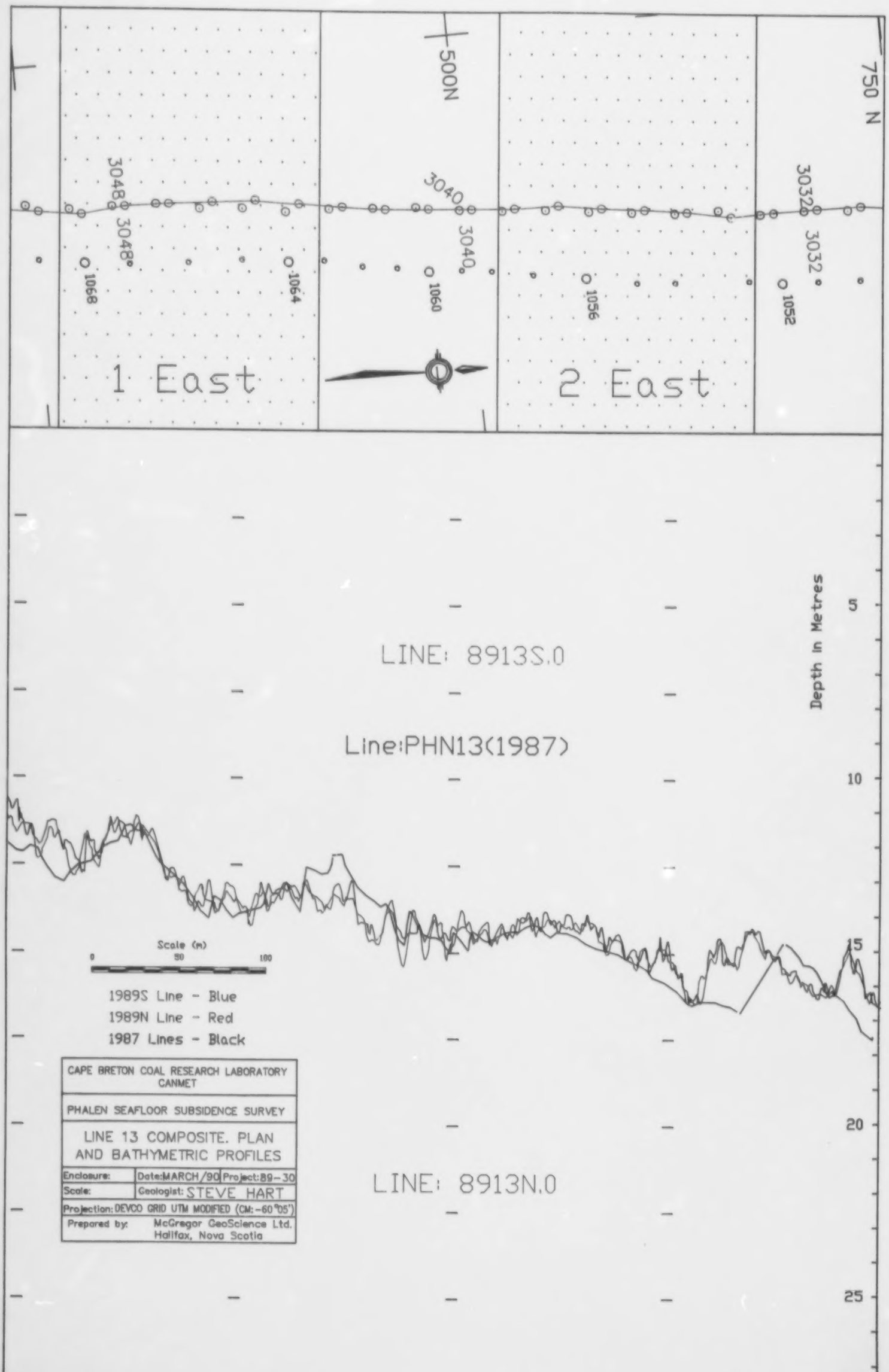
FIGURE 28





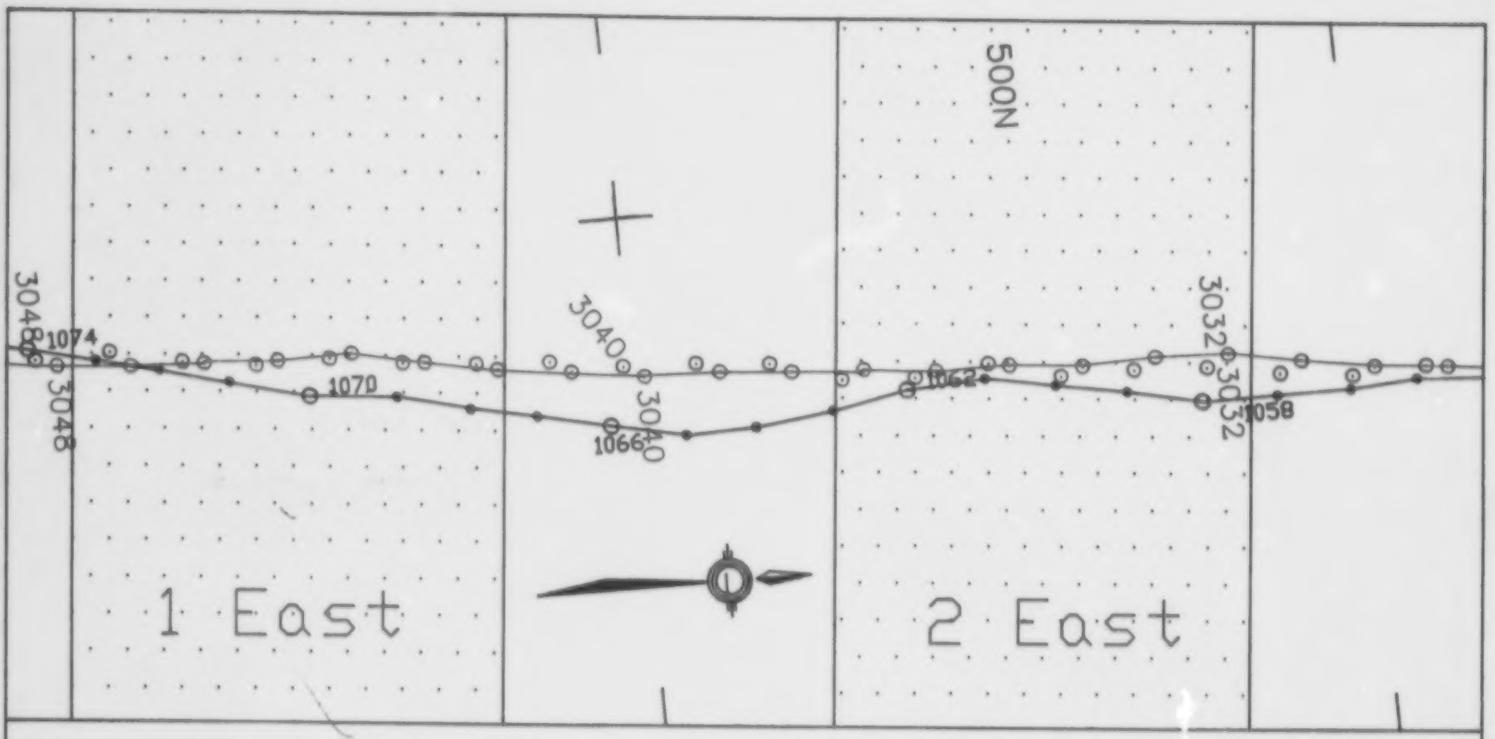
CAPE BRETON COAL RESEARCH LABORATORY CANMET		
PHALEN SEAFLOOR SUBSIDENCE SURVEY		
LINE 08 COMPOSITE. PLAN AND BATHYMETRIC PROFILES		
Enclosure:	Date:MARCH/90	Project:89-30
Scale:	Geologist: STEVE HART	
Projection: DEVCO GRID UTM MODIFIED (CM:-60°05')		
Prepared by:	McGregor GeoScience Ltd. Halifax, Nova Scotia	

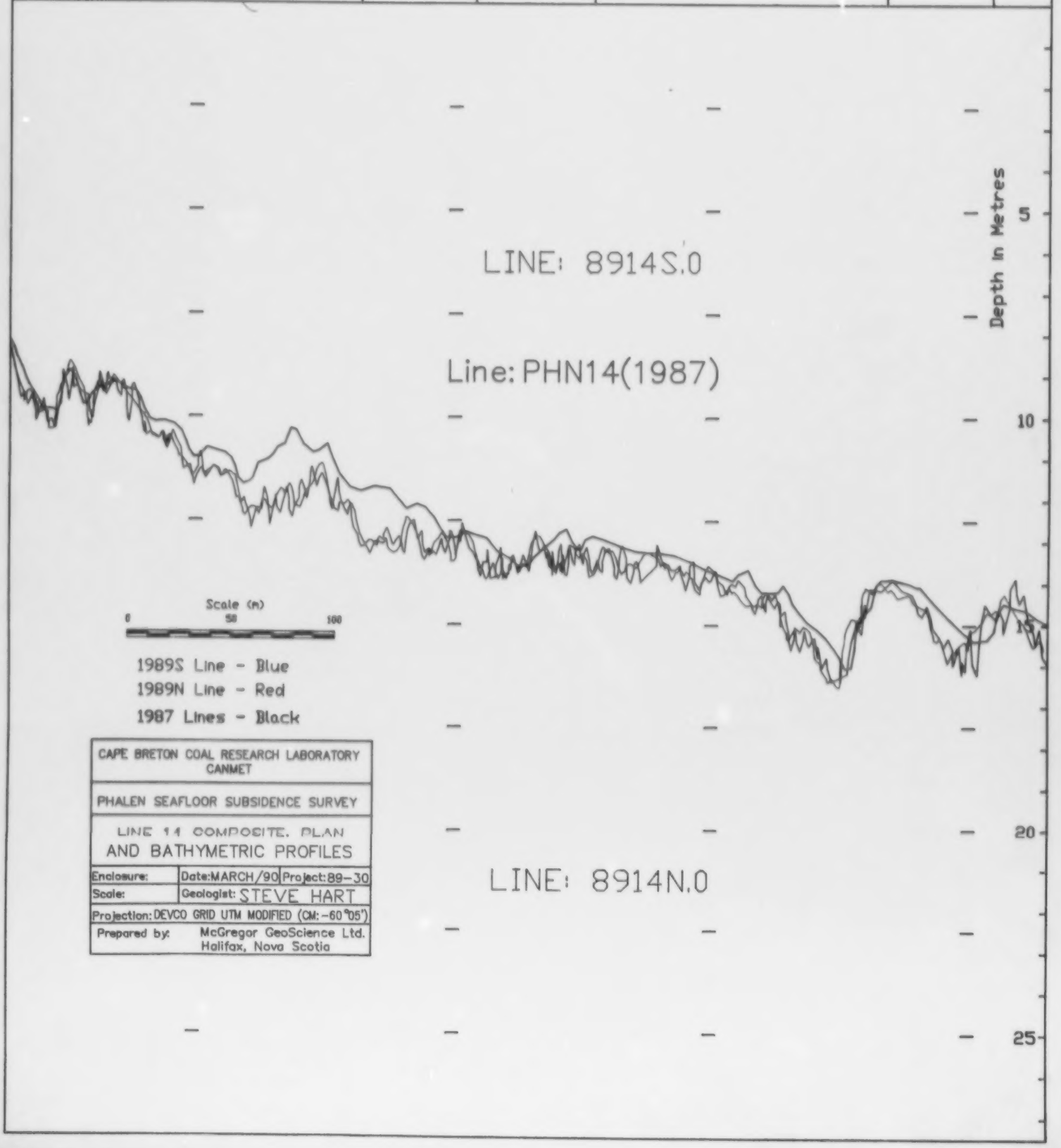
FIGURE 29



CAPE BRETON COAL RESEARCH LABORATORY CANMET	
PHALEN SEAFLOOR SUBSIDENCE SURVEY	
LINE 13 COMPOSITE. PLAN AND BATHYMETRIC PROFILES	
Enclosure:	Date:MARCH/90 Project:89-30
Scale:	Geologist: STEVE HART
Projection: DEVCO GRID UTM MODIFIED (CM:-60°05')	
Prepared by:	McGregor GeoScience Ltd. Halifax, Nova Scotia

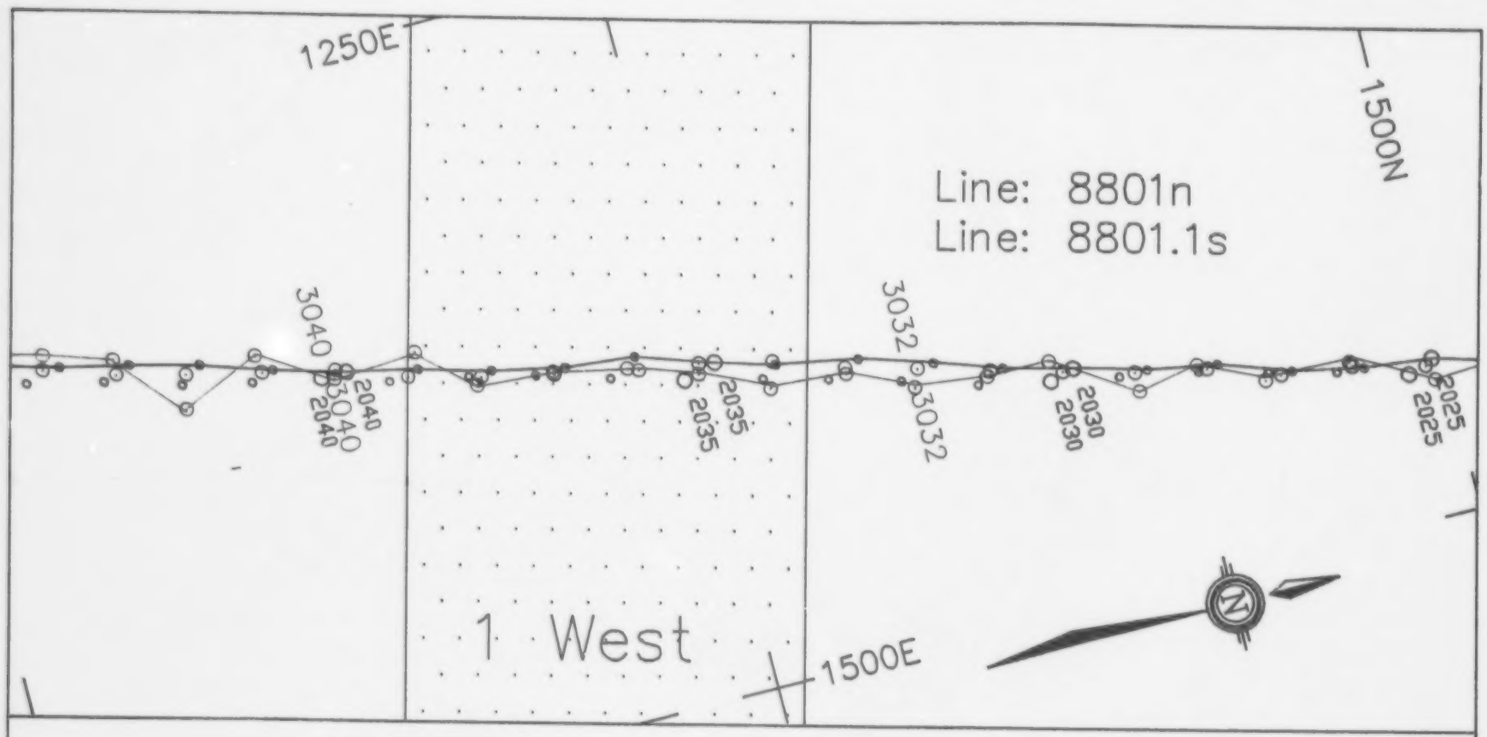
FIGURE 30

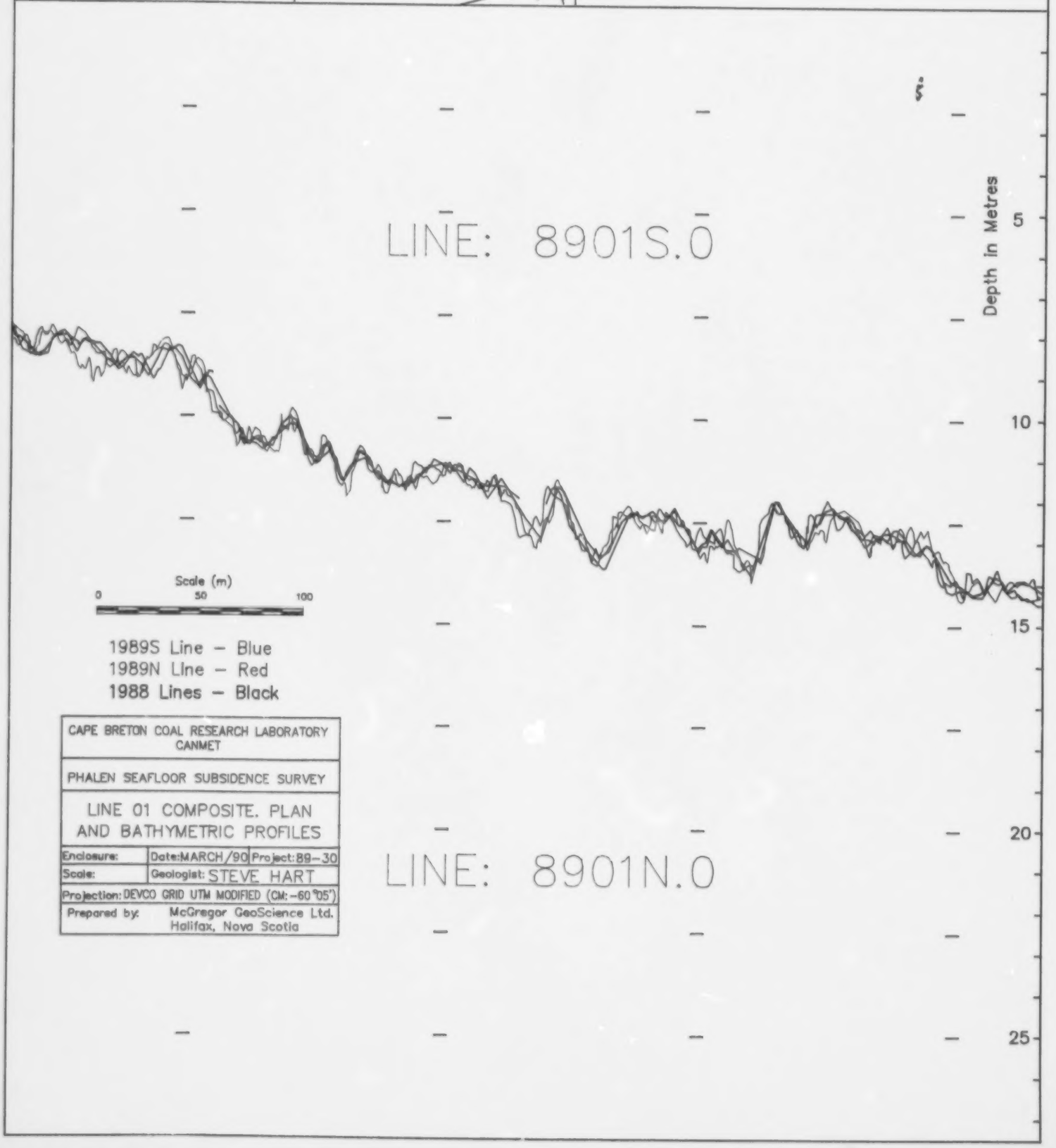




CAPE BRETON COAL RESEARCH LABORATORY CANMET		
PHALEN SEAFLOOR SUBSIDENCE SURVEY		
LINE 14 COMPOSITE PLAN AND BATHYMETRIC PROFILES		
Enclosure:	Date: MARCH/90	Project: 89-30
Scale:	Geologist: STEVE HART	
Projection: DEVCO GRID UTM MODIFIED (CM: -60°05')		
Prepared by:	McGregor GeoScience Ltd. Halifax, Nova Scotia	

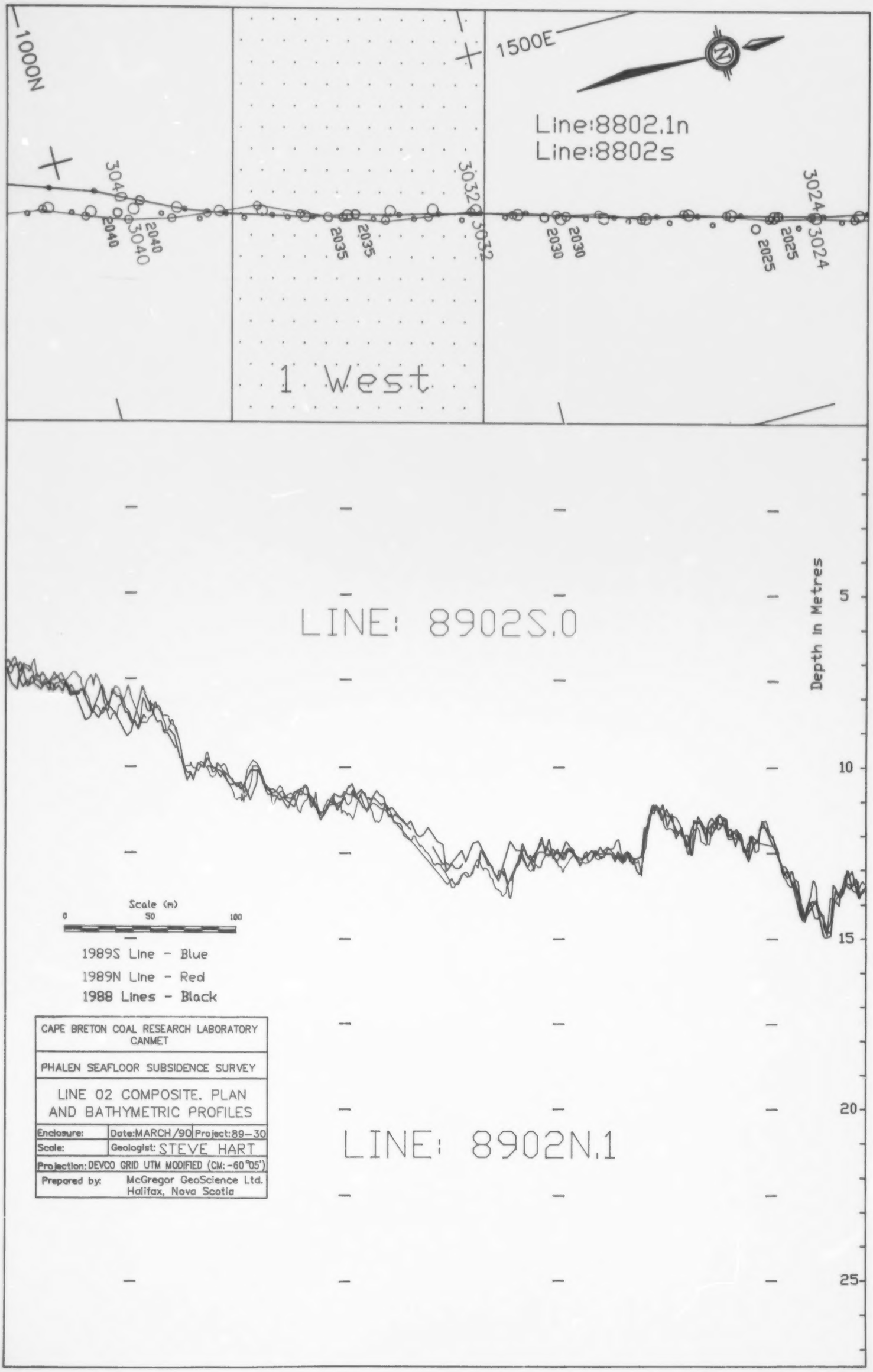
FIGURE 31





CAPE BRETON COAL RESEARCH LABORATORY CANMET		
PHALEN SEAFLOOR SUBSIDENCE SURVEY		
LINE 01 COMPOSITE. PLAN AND BATHYMETRIC PROFILES		
Enclosure:	Date: MARCH/90	Project: 89–30
Scale:	Geologist: STEVE HART	
Projection: DEVCO GRID UTM MODIFIED (CM: –60°05')		
Prepared by:	McGregor GeoScience Ltd. Halifax, Nova Scotia	

FIGURE 32



CAPE BRETON COAL RESEARCH LABORATORY CANMET	
PHALEN SEAFLOOR SUBSIDENCE SURVEY	
LINE 02 COMPOSITE. PLAN AND BATHYMETRIC PROFILES	
Enclosure:	Date:MARCH/90 Project:89-30
Scale:	Geologist: STEVE HART
Projection: DEVCO GRID UTM MODIFIED (CM:-60°05')	
Prepared by:	McGregor GeoScience Ltd. Halifax, Nova Scotia

FIGURE 33

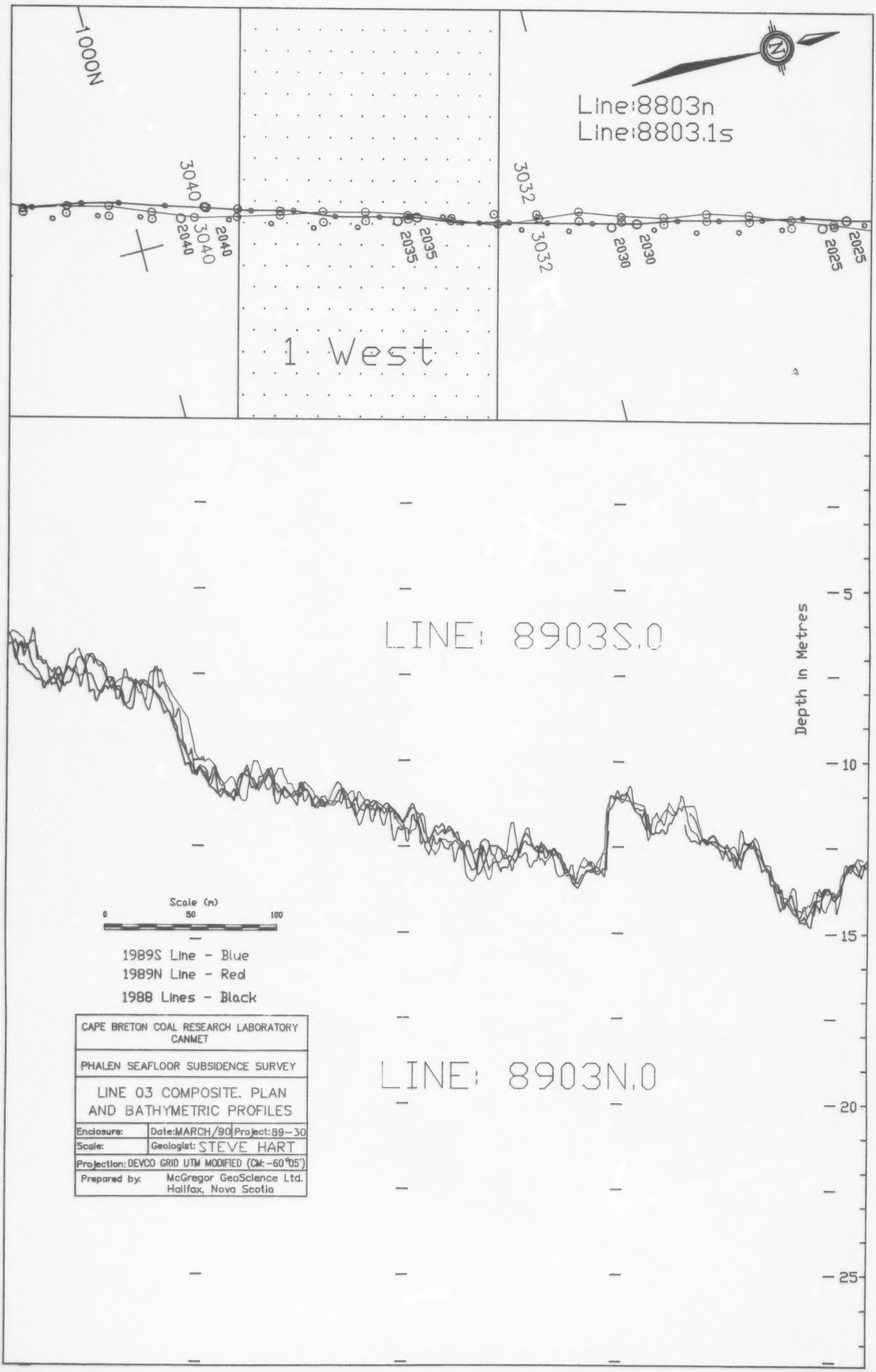
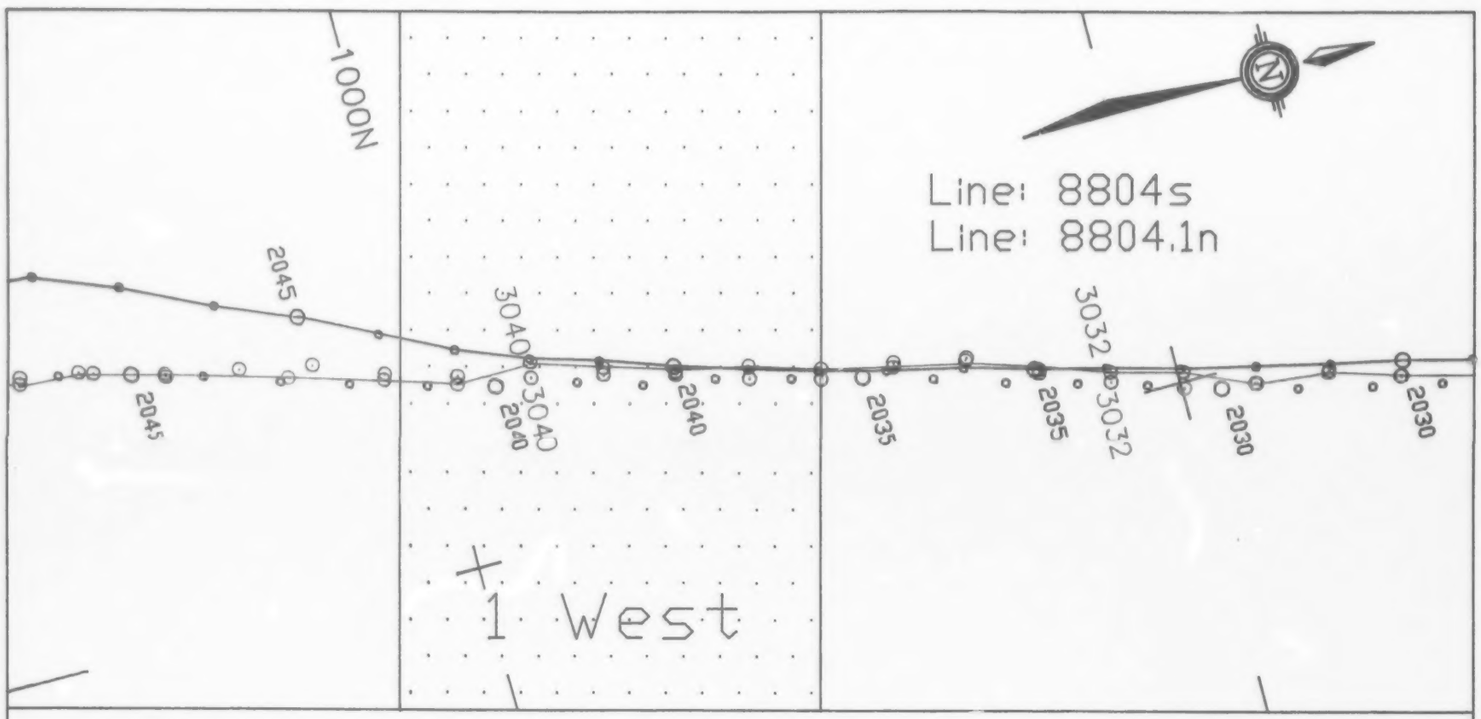
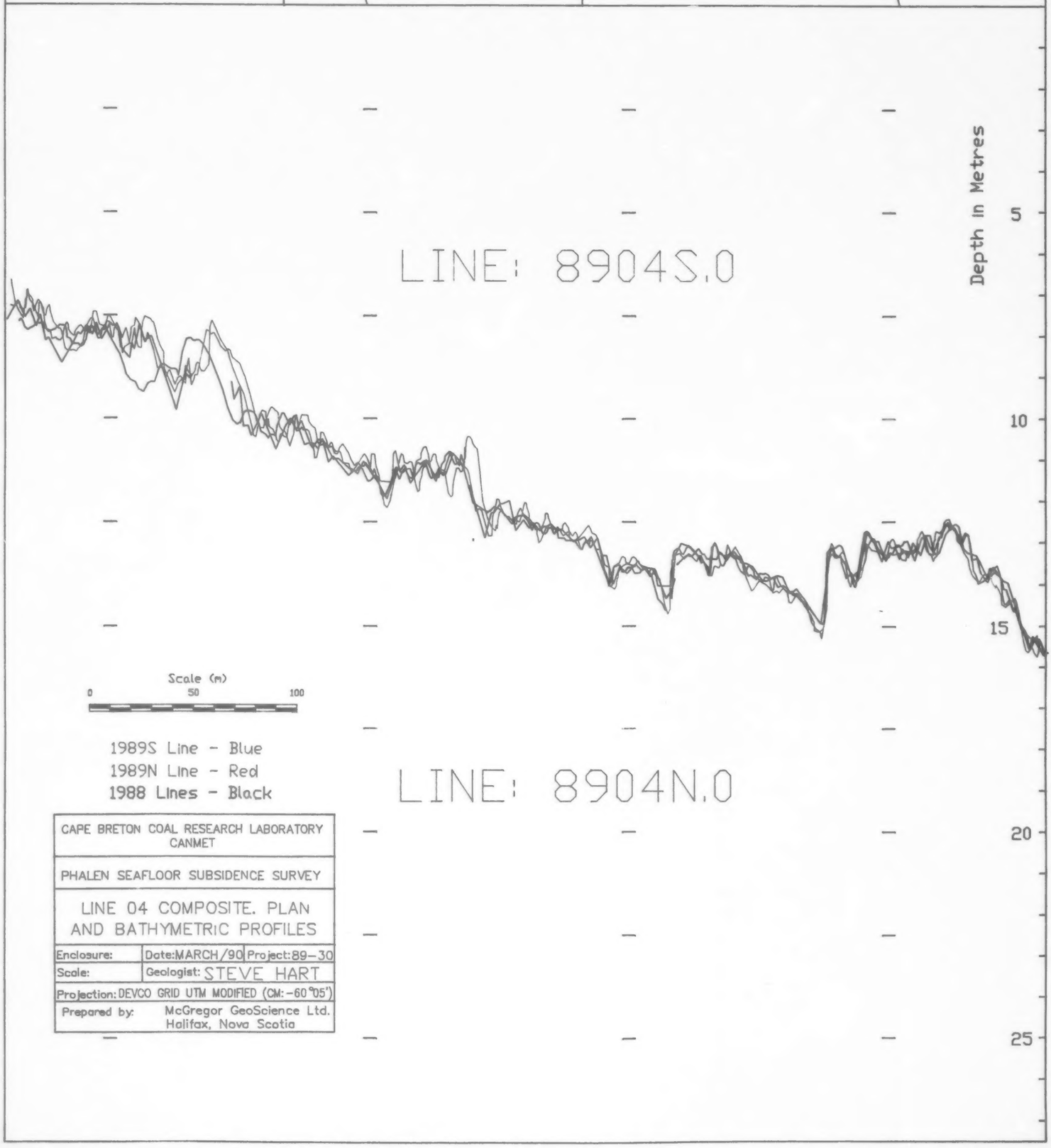

1000N
3040
3040
2040
2040
2035
2035
1 West
3032
3032
2030
2030
2025
2025
Line:8803n
Line:8803.1s
LINE: 8903S.0
LINE: 8903N.0
Depth in Metres
5
10
15
20
25
Scale (m)
0
50
100
1989S Line - Blue
1989N Line - Red
1988 Lines - Black
CAPE BRETON COAL RESEARCH LABORATORY
CANMET
PHALEN SEAFLOOR SUBSIDENCE SURVEY
LINE 03 COMPOSITE. PLAN
AND BATHYMETRIC PROFILES
Enclosure:
Date:MARCH/90
Project:89-30
Scale:
Geologist: STEVE HART
Projection: DEVCO GRID UTM MODIFIED (CM:-60°05')
Prepared by:
McGregor GeoScience Ltd.
Halifax, Nova Scotia

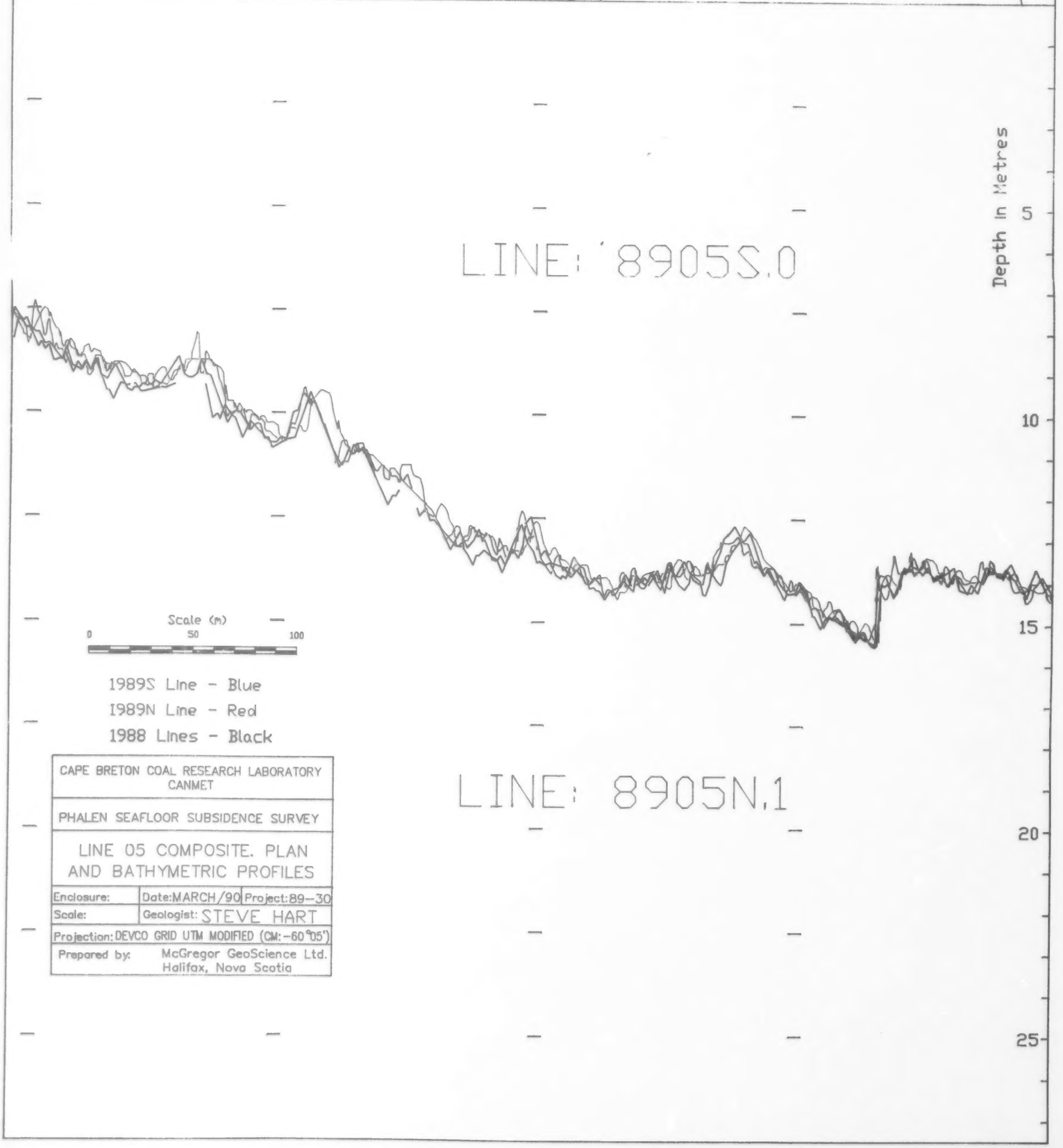
FIGURE 34





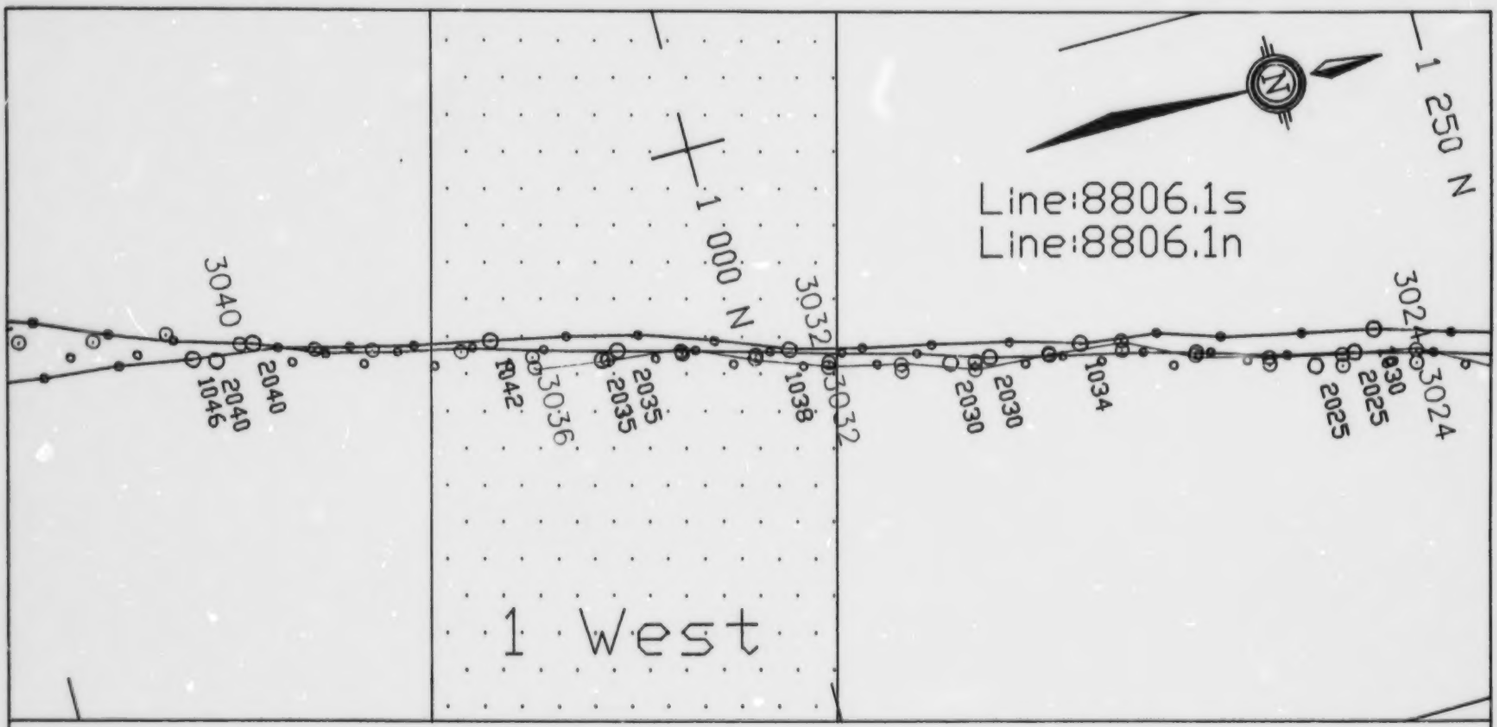
CAPE BRETON COAL RESEARCH LABORATORY CANMET	
PHALEN SEAFLOOR SUBSIDENCE SURVEY	
LINE 04 COMPOSITE. PLAN AND BATHYMETRIC PROFILES	
Enclosure:	Date:MARCH/90 Project:89-30
Scale:	Geologist: STEVE HART
Projection: DEVCO GRID UTM MODIFIED (CM: -60°05')	
Prepared by:	McGregor GeoScience Ltd. Halifax, Nova Scotia

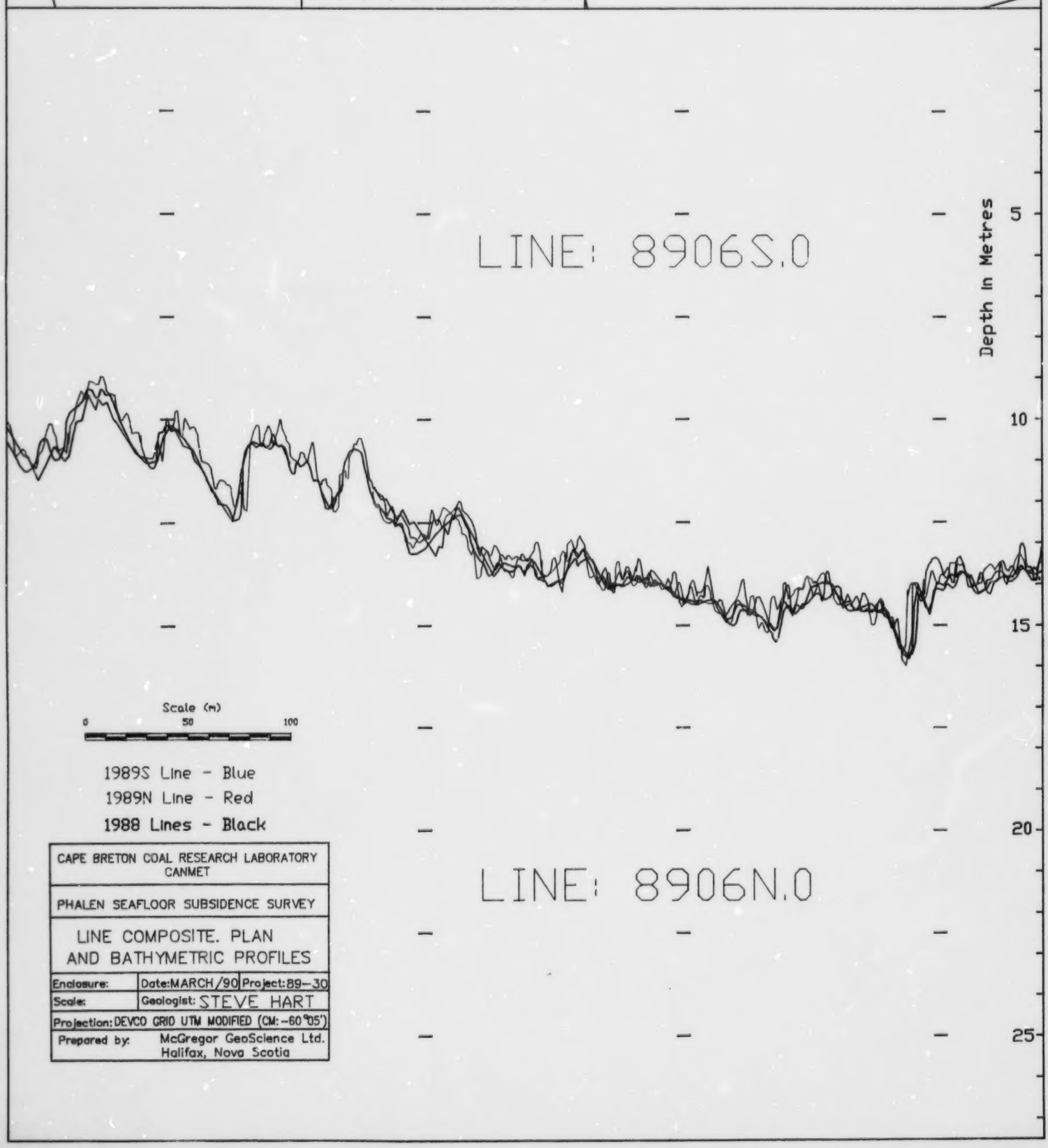
FIGURE 35



CAPE BRETON COAL RESEARCH LABORATORY CANMET		
PHALEN SEAFLOOR SUBSIDENCE SURVEY		
LINE 05 COMPOSITE. PLAN AND BATHYMETRIC PROFILES		
Enclosure:	Date:MARCH/90	Project:89-30
Scale:	Geologist: STEVE HART	
Projection: DEVCO GRID UTM MODIFIED (CM:-60°05')		
Prepared by:	McGregor GeoScience Ltd. Halifax, Nova Scotia	

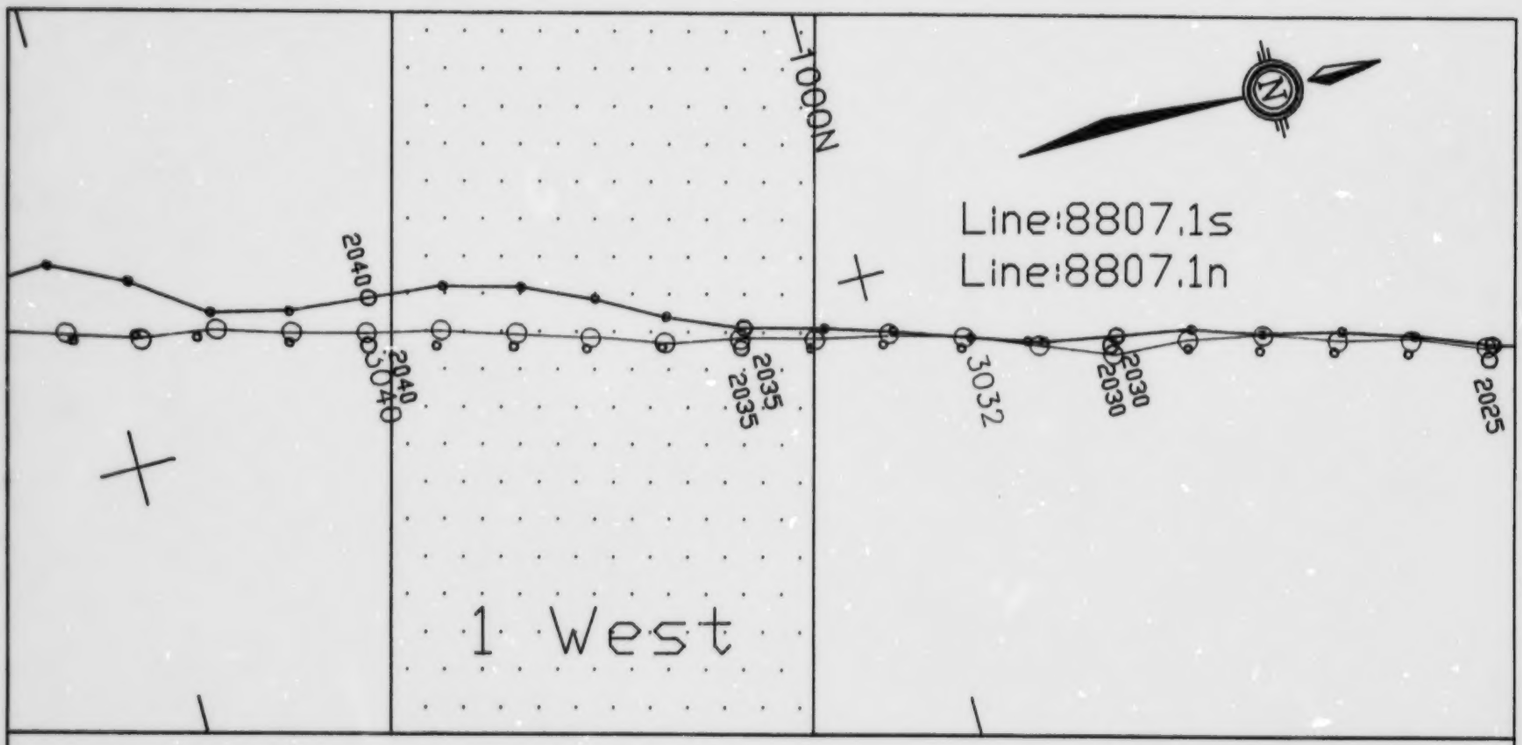
FIGURE 36

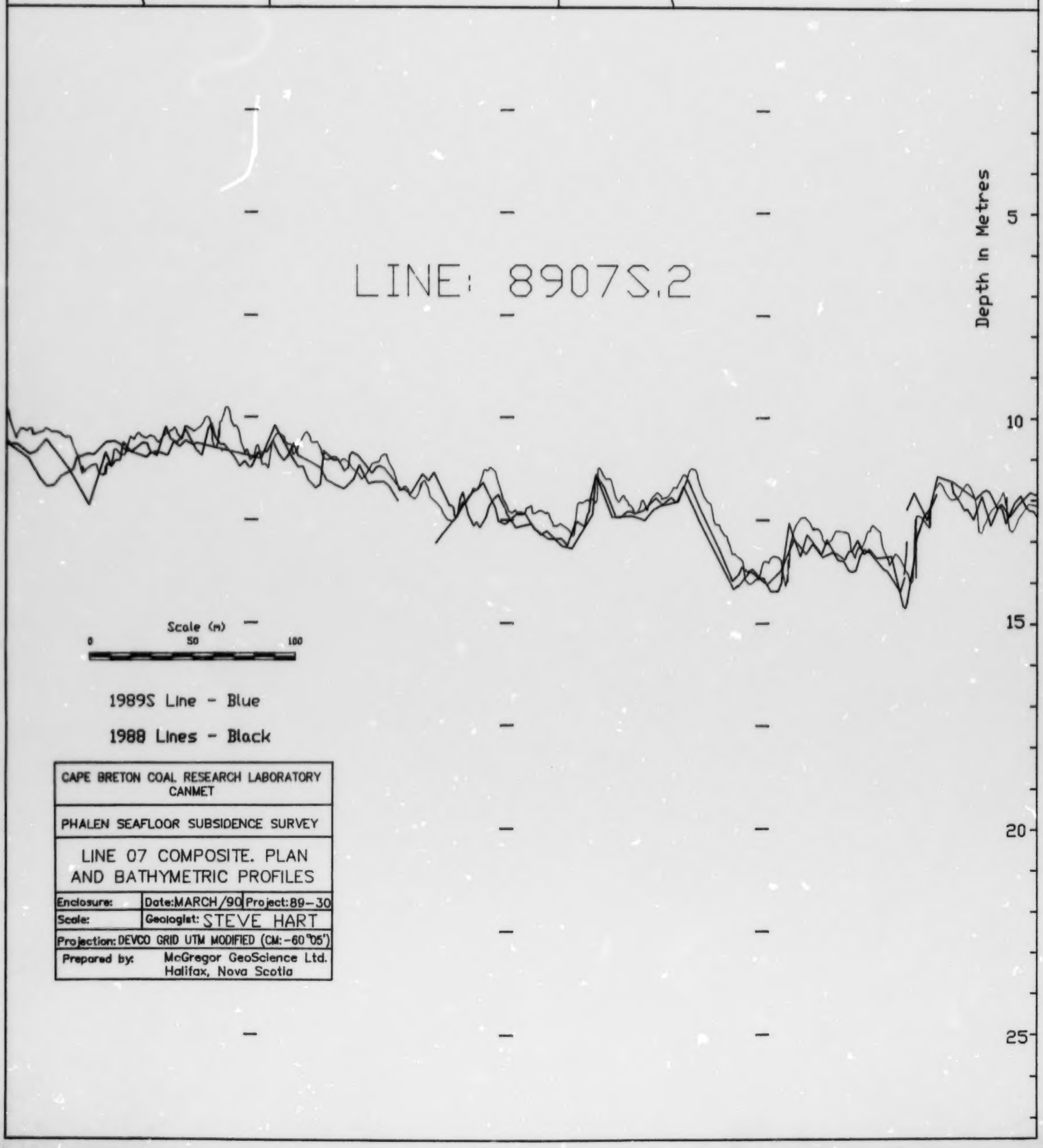




CAPE BRETON COAL RESEARCH LABORATORY CANMET		
PHALEN SEAFLOOR SUBSIDENCE SURVEY		
LINE COMPOSITE. PLAN AND BATHYMETRIC PROFILES		
Enclosure:	Date:MARCH/90	Project:89-30
Scale:	Geologist: STEVE HART	
Projection: DEVCO GRID UTM MODIFIED (CM:-60°05')		
Prepared by:	McGregor GeoScience Ltd. Halifax, Nova Scotia	

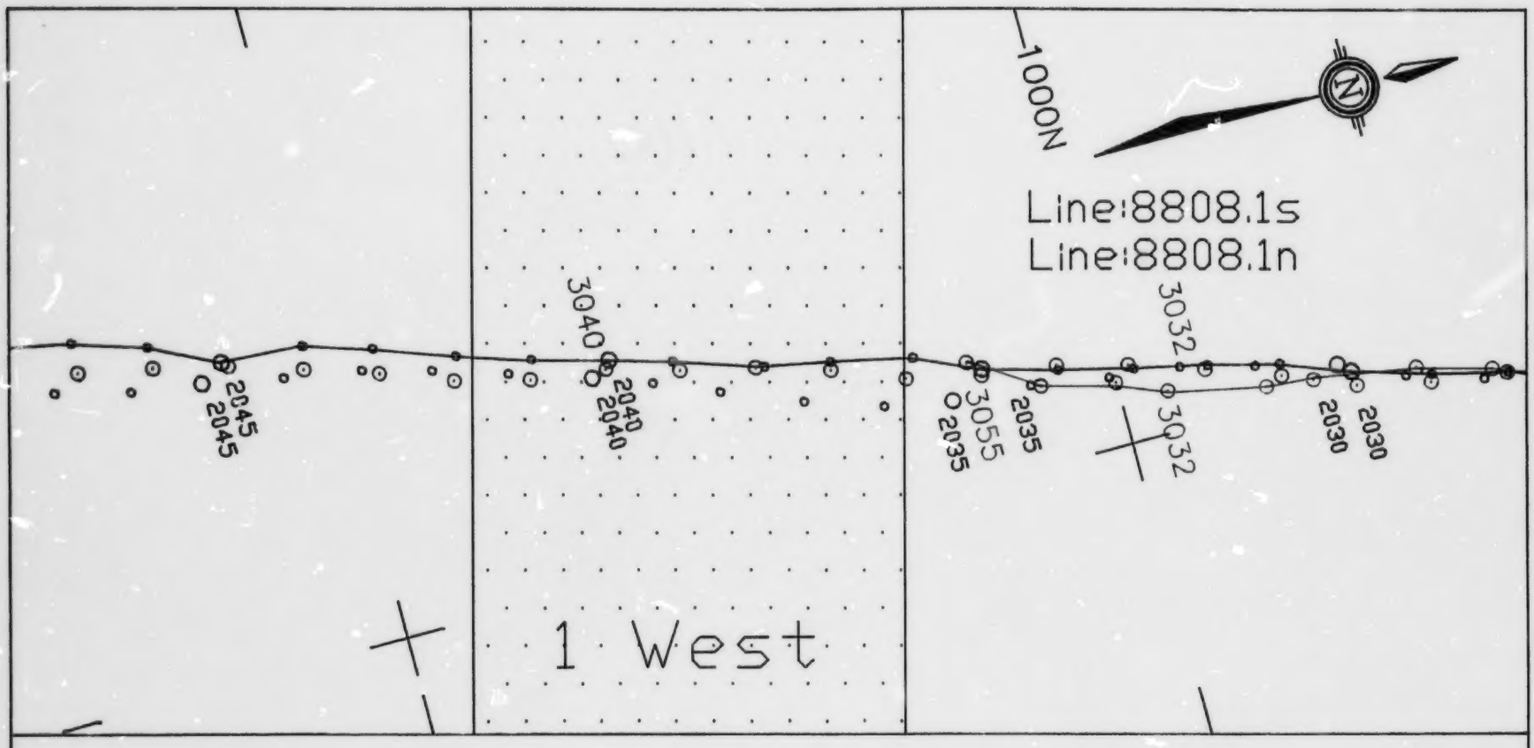
FIGURE 37

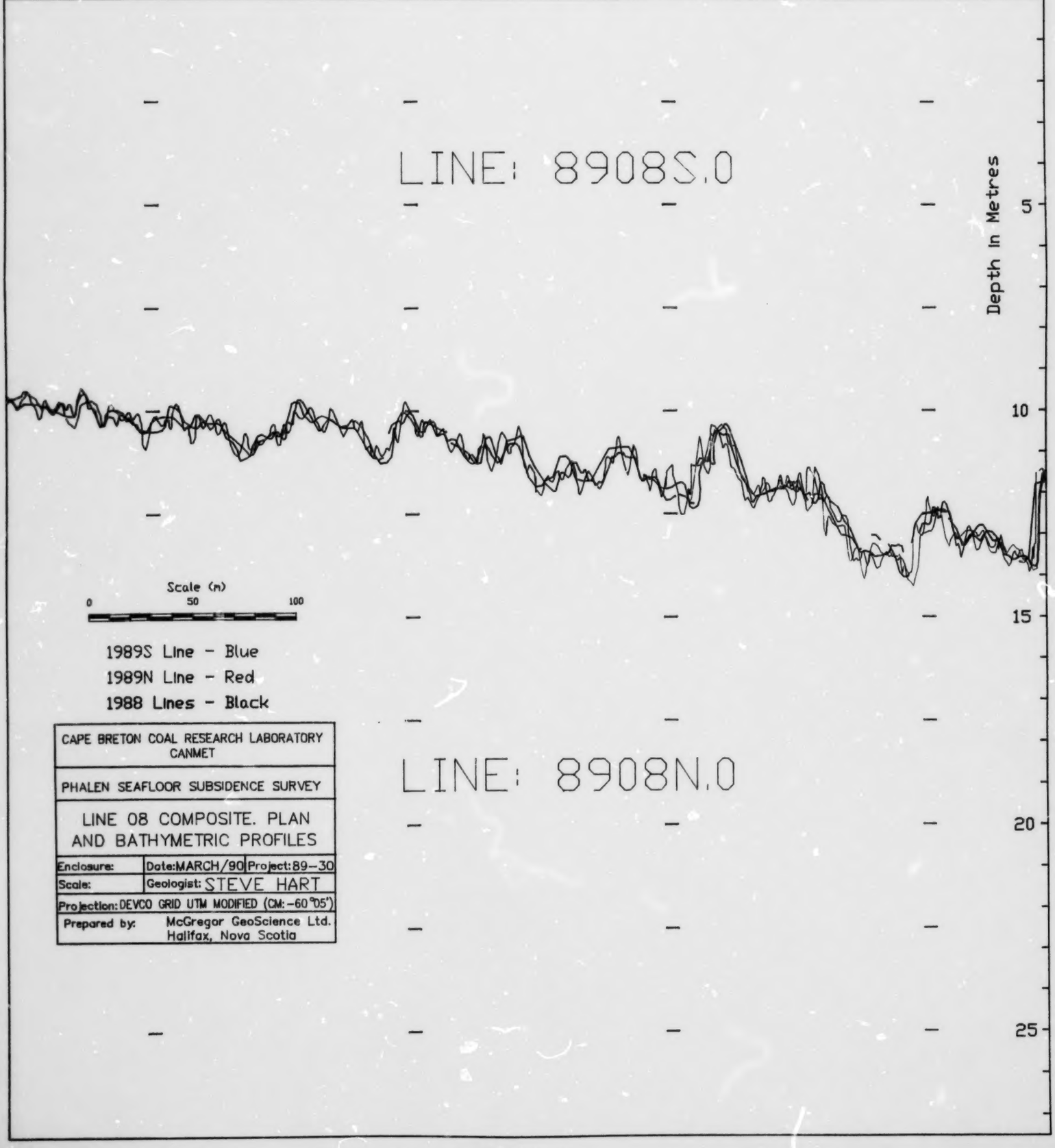




CAPE BRETON COAL RESEARCH LABORATORY CANMET	
PHALEN SEAFLOOR SUBSIDENCE SURVEY	
LINE 07 COMPOSITE. PLAN AND BATHYMETRIC PROFILES	
Enclosure:	Date:MARCH/90 Project:89-30
Scale:	Geologist: STEVE HART
Projection: DEVCO GRID UTM MODIFIED (CM:-60°05')	
Prepared by:	McGregor GeoScience Ltd. Halifax, Nova Scotia

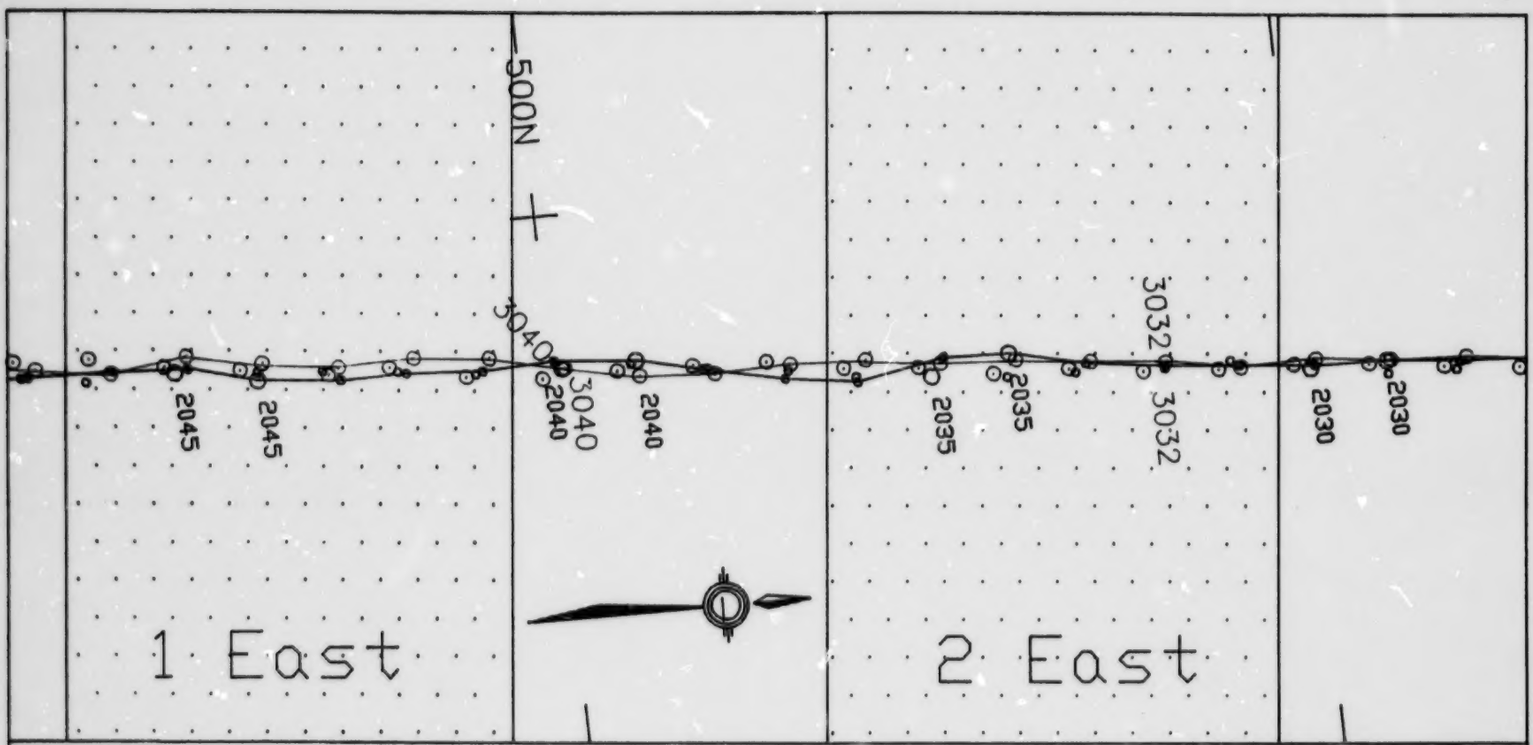
FIGURE 38

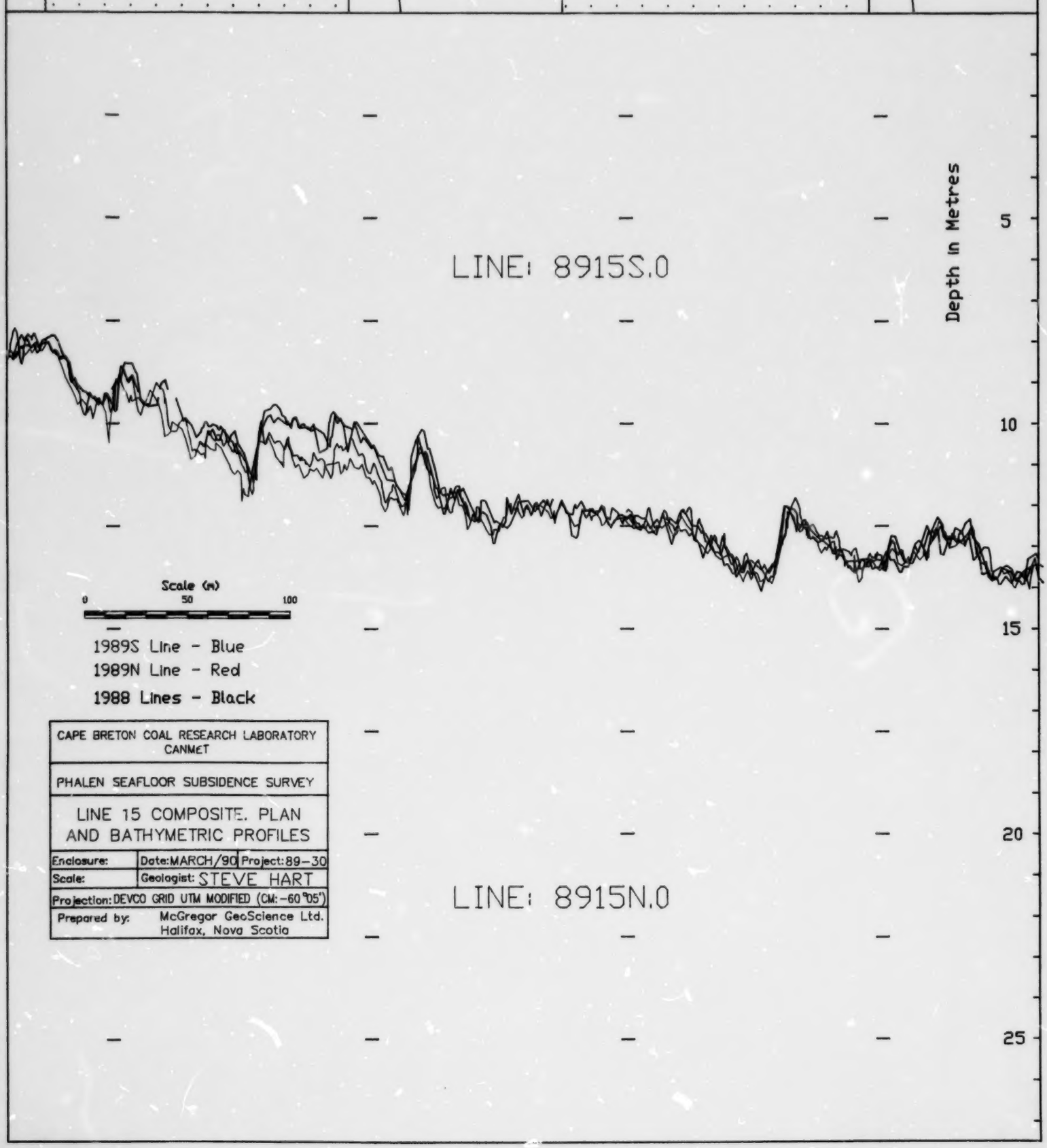




CAPE BRETON COAL RESEARCH LABORATORY CANMET		
PHALEN SEAFLOOR SUBSIDENCE SURVEY		
LINE 08 COMPOSITE. PLAN AND BATHYMETRIC PROFILES		
Enclosure:	Date:MARCH/90	Project:89-30
Scale:	Geologist: STEVE HART	
Projection: DEVCO GRID UTM MODIFIED (CM: -60°05')		
Prepared by:	McGregor GeoScience Ltd. Halifax, Nova Scotia	

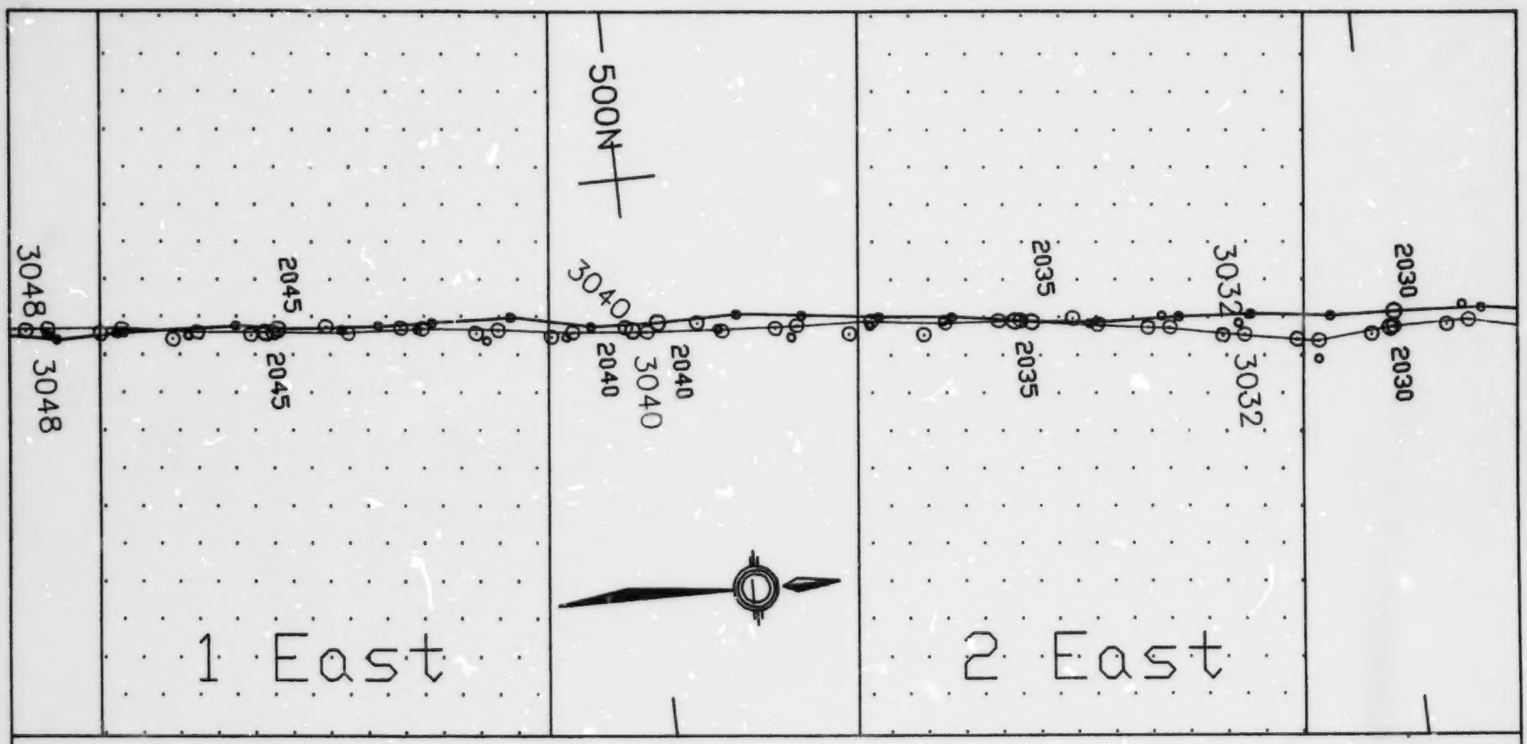
FIGURE 39

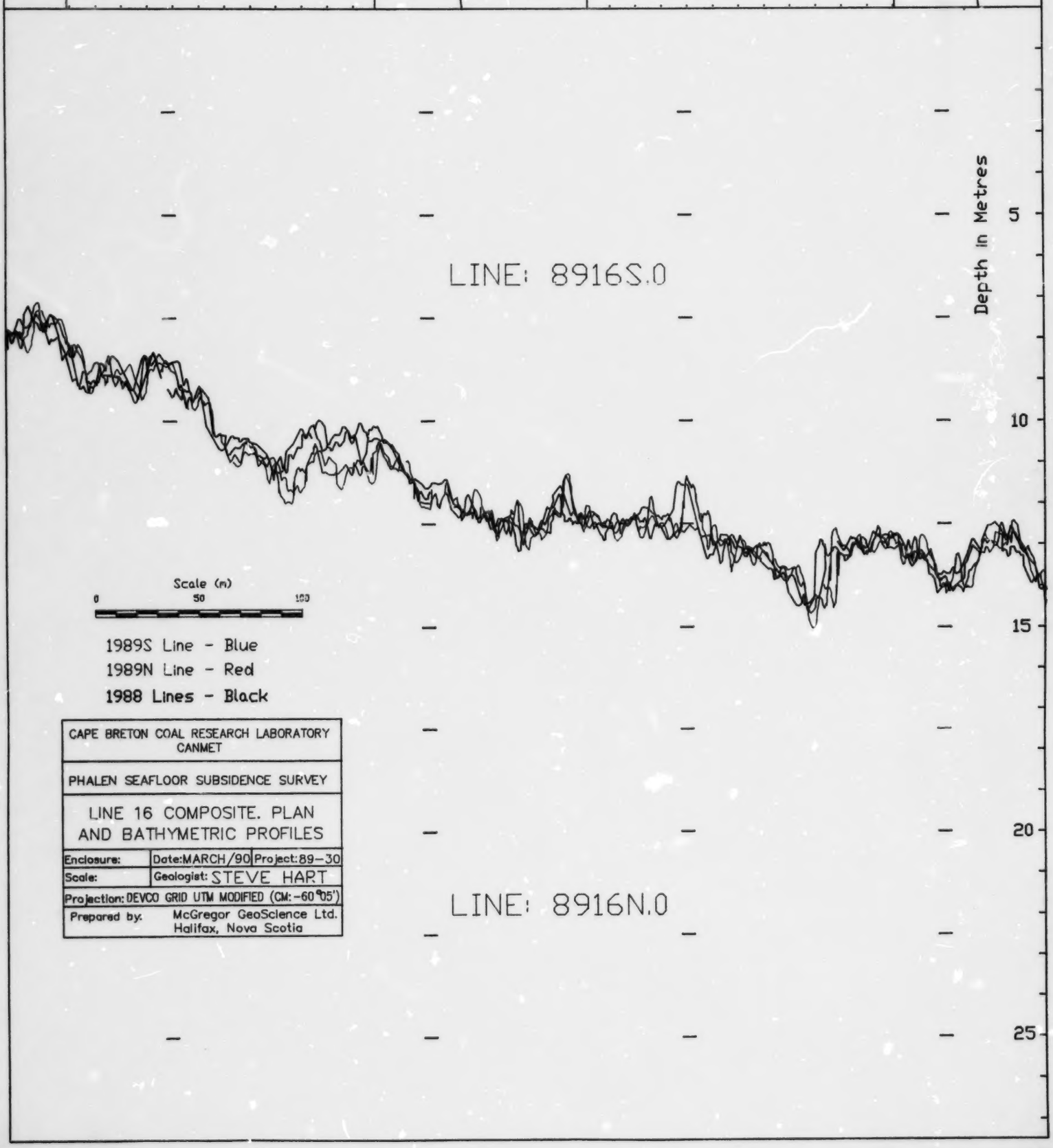




CAPE BRETON COAL RESEARCH LABORATORY CANMET		
PHALEN SEAFLOOR SUBSIDENCE SURVEY		
LINE 15 COMPOSITE. PLAN AND BATHYMETRIC PROFILES		
Enclosure:	Date: MARCH/90	Project: 89-30
Scale:	Geologist: STEVE HART	
Projection: DEVCO GRID UTM MODIFIED (CM: -60°05')		
Prepared by:	McGregor GeoScience Ltd. Halifax, Nova Scotia	

FIGURE 40





CAPE BRETON COAL RESEARCH LABORATORY CANMET		
PHALEN SEAFLOOR SUBSIDENCE SURVEY		
LINE 16 COMPOSITE. PLAN AND BATHYMETRIC PROFILES		
Enclosure:	Date: MARCH/90	Project: 89-30
Scale:	Geologist: STEVE HART	
Projection: DEVCO GRID UTM MODIFIED (CM: -60°05')		
Prepared by:	McGregor GeoScience Ltd. Halifax, Nova Scotia	

FIGURE 41

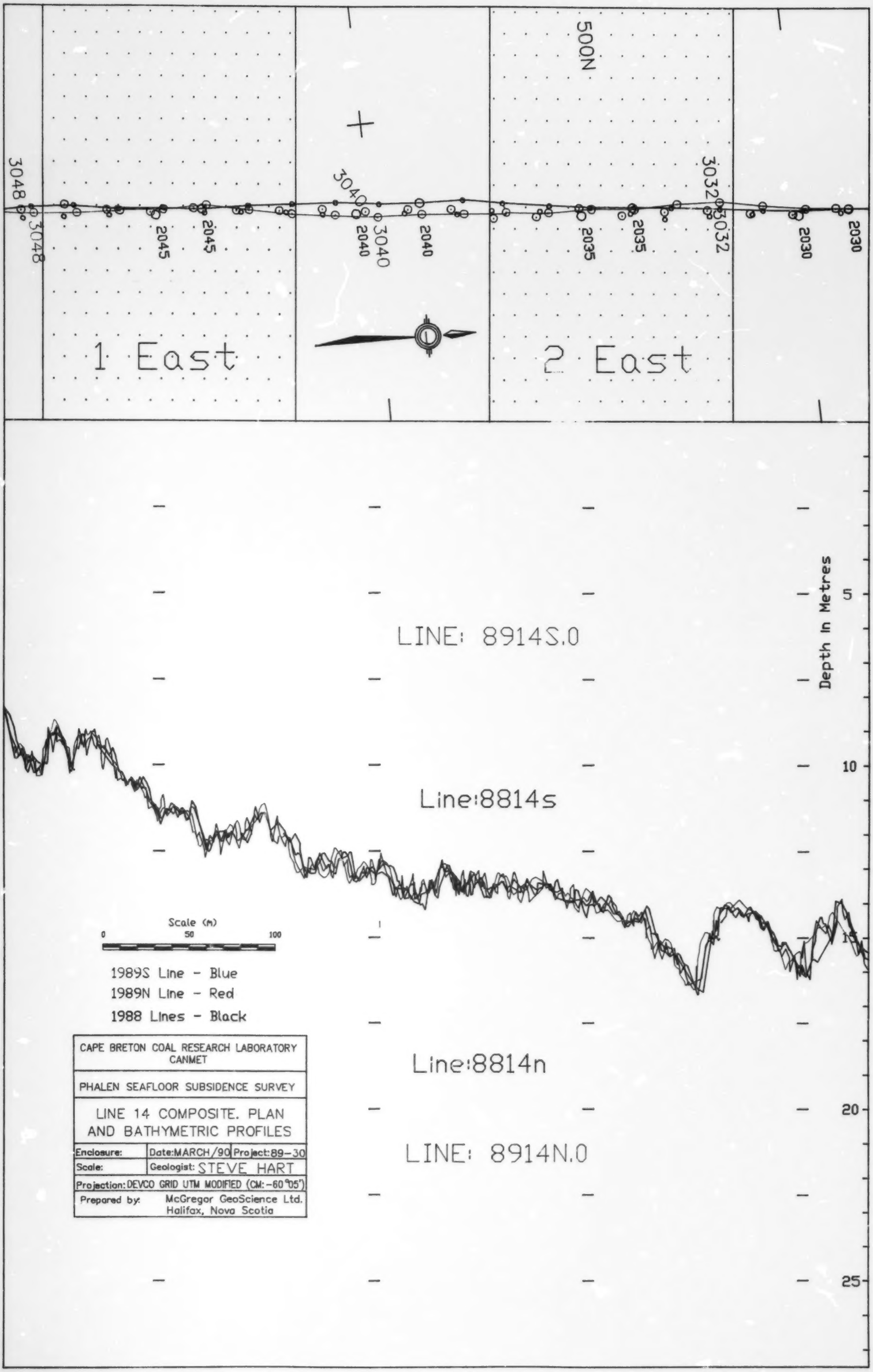

500N
3048
3048
2045
2045
3040
3040
2040
2040
3032
3032
2035
2035
2030
2030
1 East
2 East
LINE: 8914S.0
Line:8814s
Line:8814n
LINE: 8914N.0
Depth in Metres
5
10
20
25
Scale (m)
0
50
100
1989S Line - Blue
1989N Line - Red
1988 Lines - Black
CAPE BRETON COAL RESEARCH LABORATORY
CANMET
PHALEN SEAFLOOR SUBSIDENCE SURVEY
LINE 14 COMPOSITE. PLAN
AND BATHYMETRIC PROFILES
Enclosure:
Date:MARCH/90
Project:89-30
Scale:
Geologist: STEVE HART
Projection: DEVCO GRID UTM MODIFIED (CM:-60°05')
Prepared by:
McGregor GeoScience Ltd.
Halifax, Nova Scotia

FIGURE 42

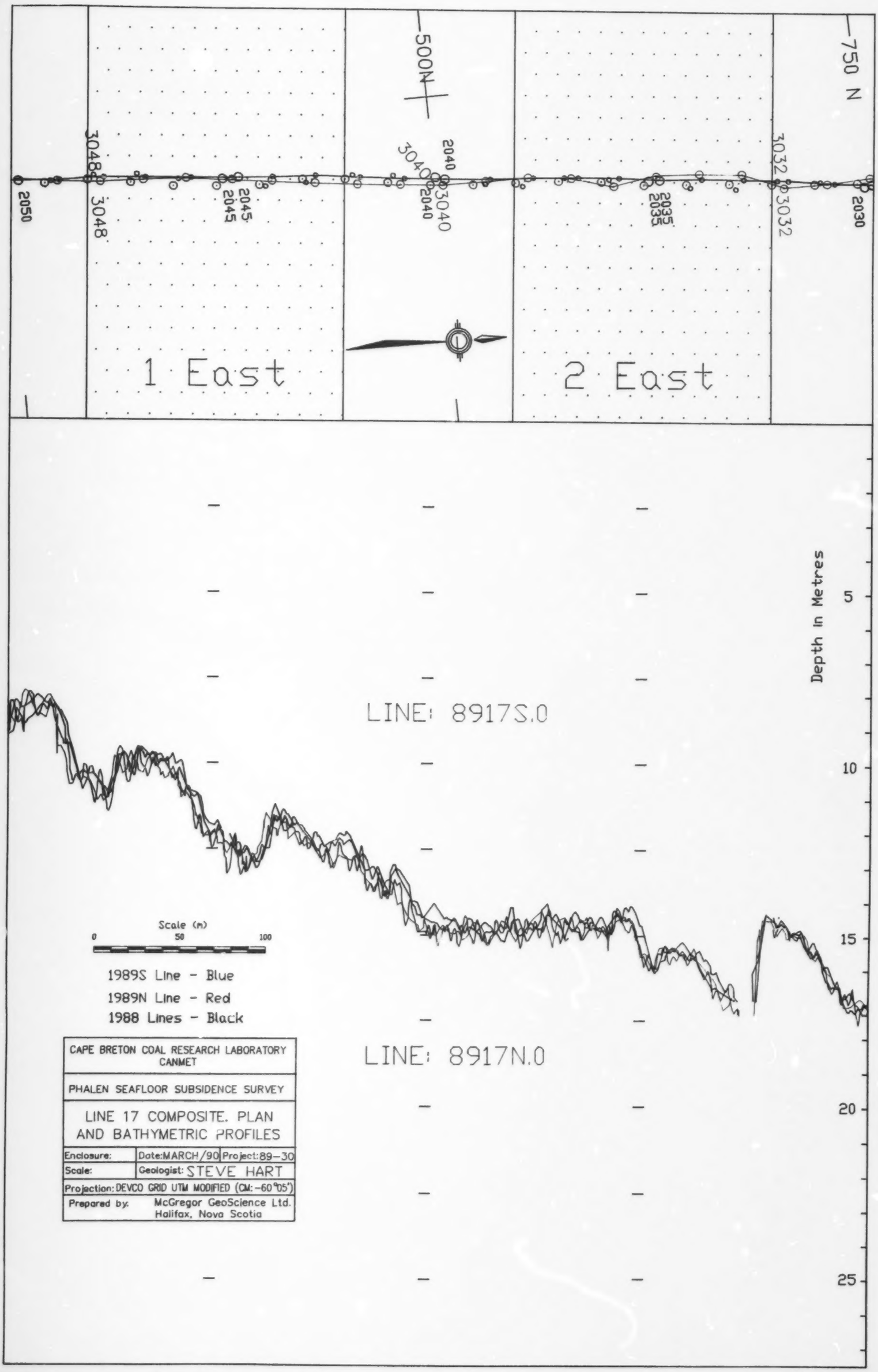

500N
750 N
1 East
2 East
3048
2050
3040
2040
2045
2035
3032
2030
LINE: 8917S.0
LINE: 8917N.0
Depth in Metres
5
10
15
20
25
Scale (m)
0
50
100
1989S Line - Blue
1989N Line - Red
1988 Lines - Black
CAPE BRETON COAL RESEARCH LABORATORY
CANMET
PHALEN SEAFLOOR SUBSIDENCE SURVEY
LINE 17 COMPOSITE. PLAN
AND BATHYMETRIC PROFILES
Enclosure:
Date:MARCH/90
Project:89-30
Scale:
Geologist: STEVE HART
Projection: DEVCO GRID UTM MODIFIED (CM: -60°05')
Prepared by:
McGregor GeoScience Ltd.
Halifax, Nova Scotia

FIGURE 43

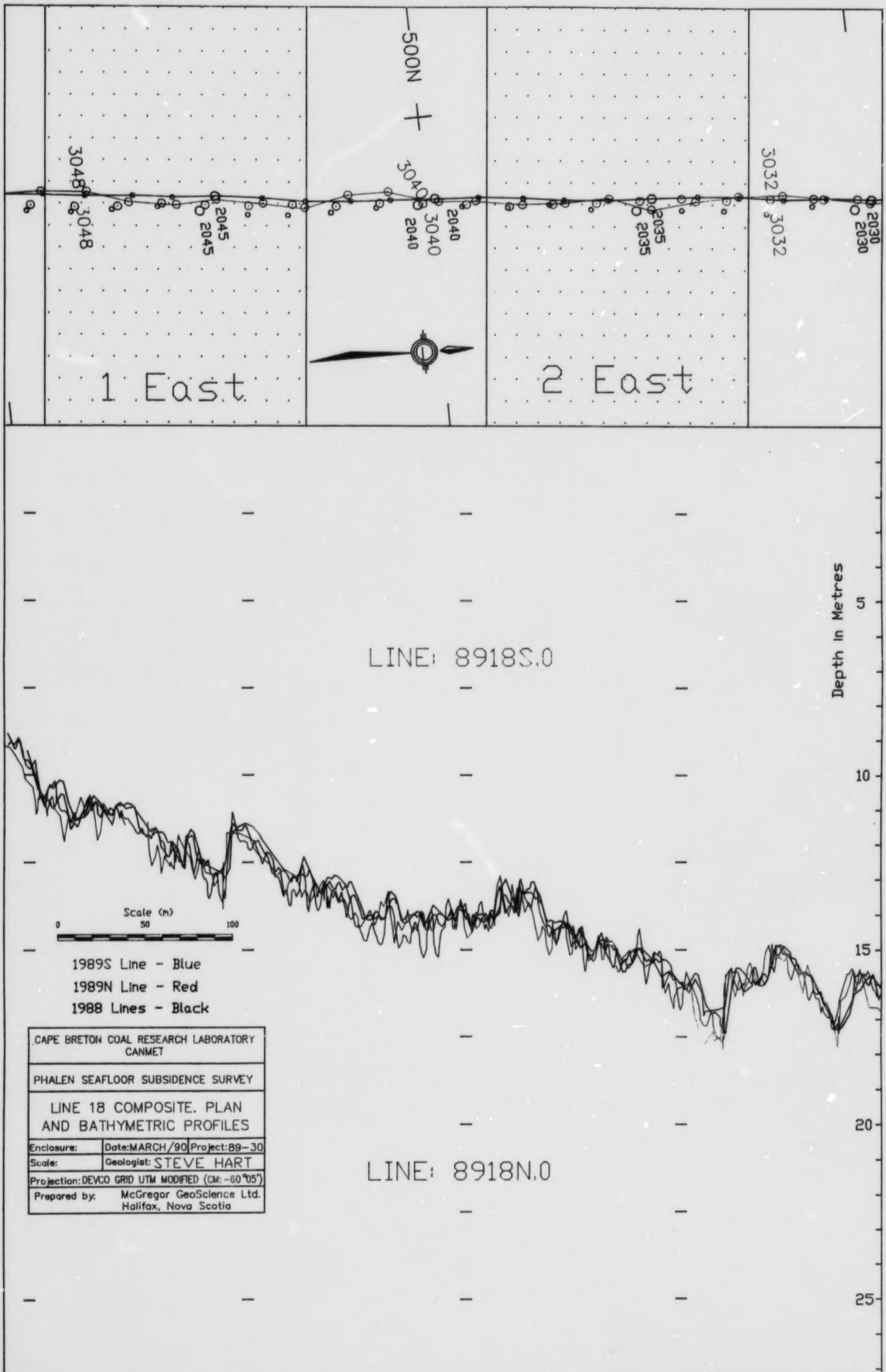

500N
1 East
2 East
3048
3048
2045
2045
3040
3040
2040
2040
3032
3032
2035
2035
2030
2030
LINE: 8918S.0
LINE: 8918N.0
Depth in Metres
5
10
15
20
25
Scale (m)
0
50
100
1989S Line - Blue
1989N Line - Red
1988 Lines - Black
CAPE BRETON COAL RESEARCH LABORATORY
CANMET
PHALEN SEAFLOOR SUBSIDENCE SURVEY
LINE 18 COMPOSITE. PLAN
AND BATHYMETRIC PROFILES
Enclosure:
Date:MARCH/90
Project:89-30
Scale:
Geologist: STEVE HART
Projection: DEVCO GRID UTM MODIFIED (CM: -60°05')
Prepared by:
McGregor GeoScience Ltd.
Halifax, Nova Scotia

FIGURE 44

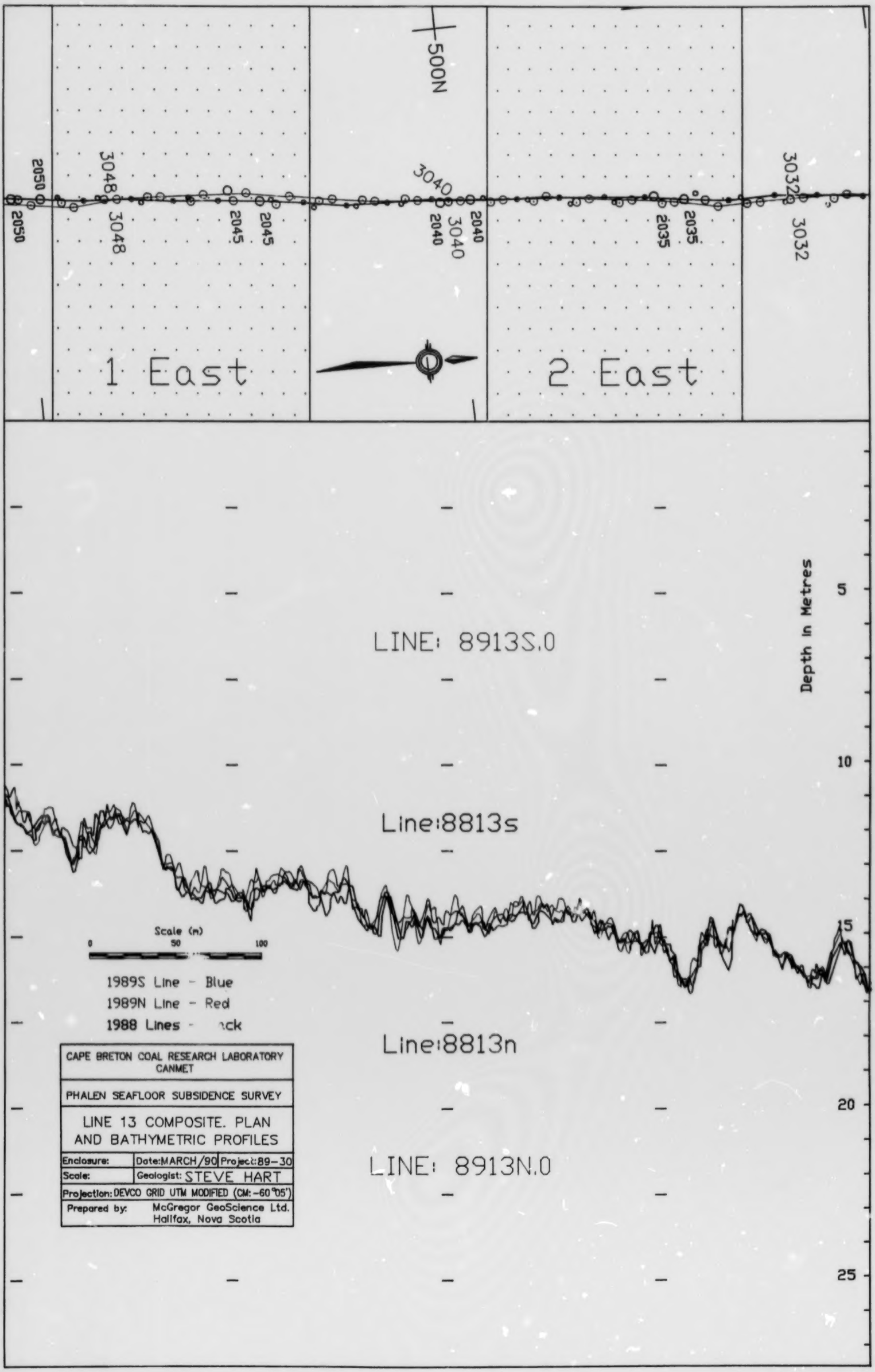
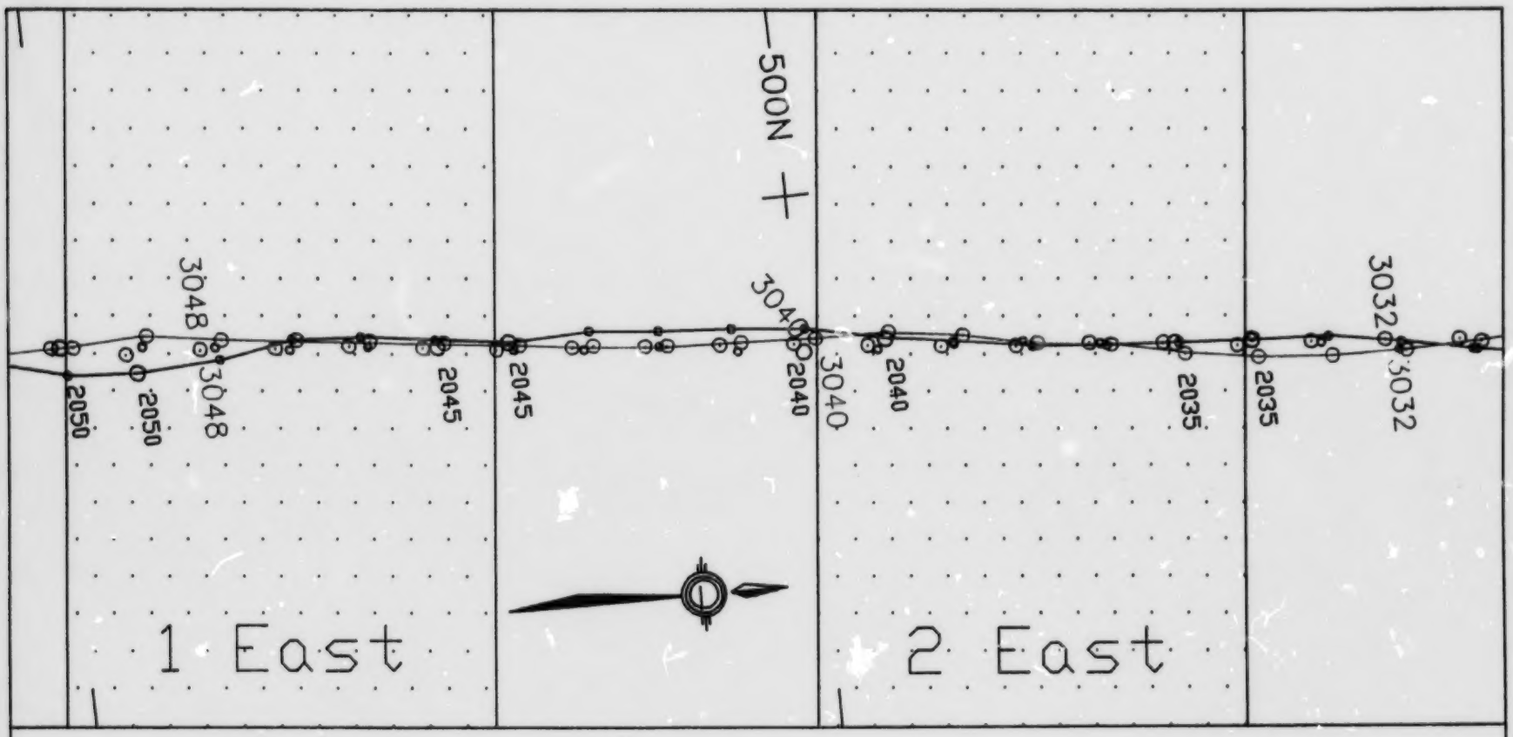
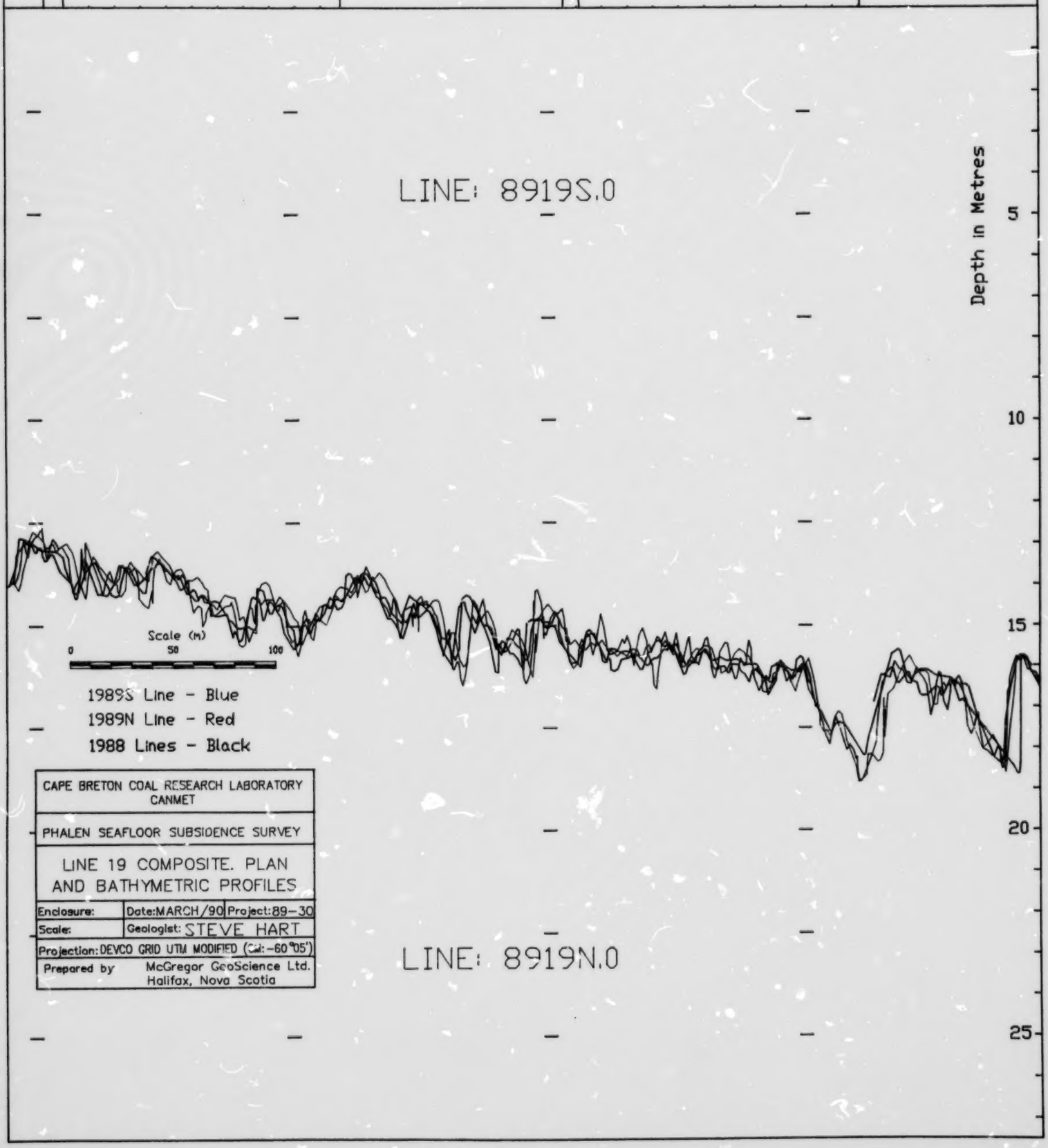

500N
2050
3048
2045
3040
2040
3032
2035
1 East
2 East
Depth in Metres
5
10
15
20
25
LINE: 8913S.0
Line:8813s
Line:8813n
LINE: 8913N.0
Scale (m)
0
50
100
1989S Line - Blue
1989N Line - Red
1988 Lines - Black
CAPE BRETON COAL RESEARCH LABORATORY
CANMET
PHALEN SEAFLOOR SUBSIDENCE SURVEY
LINE 13 COMPOSITE. PLAN
AND BATHYMETRIC PROFILES
Enclosure:
Date:MARCH/90
Project:89-30
Scale:
Geologist: STEVE HART
Projection: DEVCO GRID UTM MODIFIED (CM:-60°05')
Prepared by:
McGregor GeoScience Ltd.
Halifax, Nova Scotia

FIGURE 45





CAPE BRETON COAL RESEARCH LABORATORY CANMET	
PHALEN SEAFLOOR SUBSIDENCE SURVEY	
LINE 19 COMPOSITE. PLAN AND BATHYMETRIC PROFILES	
Enclosure:	Date:MARCH/90 Project:89-30
Scale:	Geologist: STEVE HART
Projection: DEVCO GRID UTM MODIFIED (CM: -60°05')	
Prepared by	McGregor GeoScience Ltd. Halifax, Nova Scotia

FIGURE 46

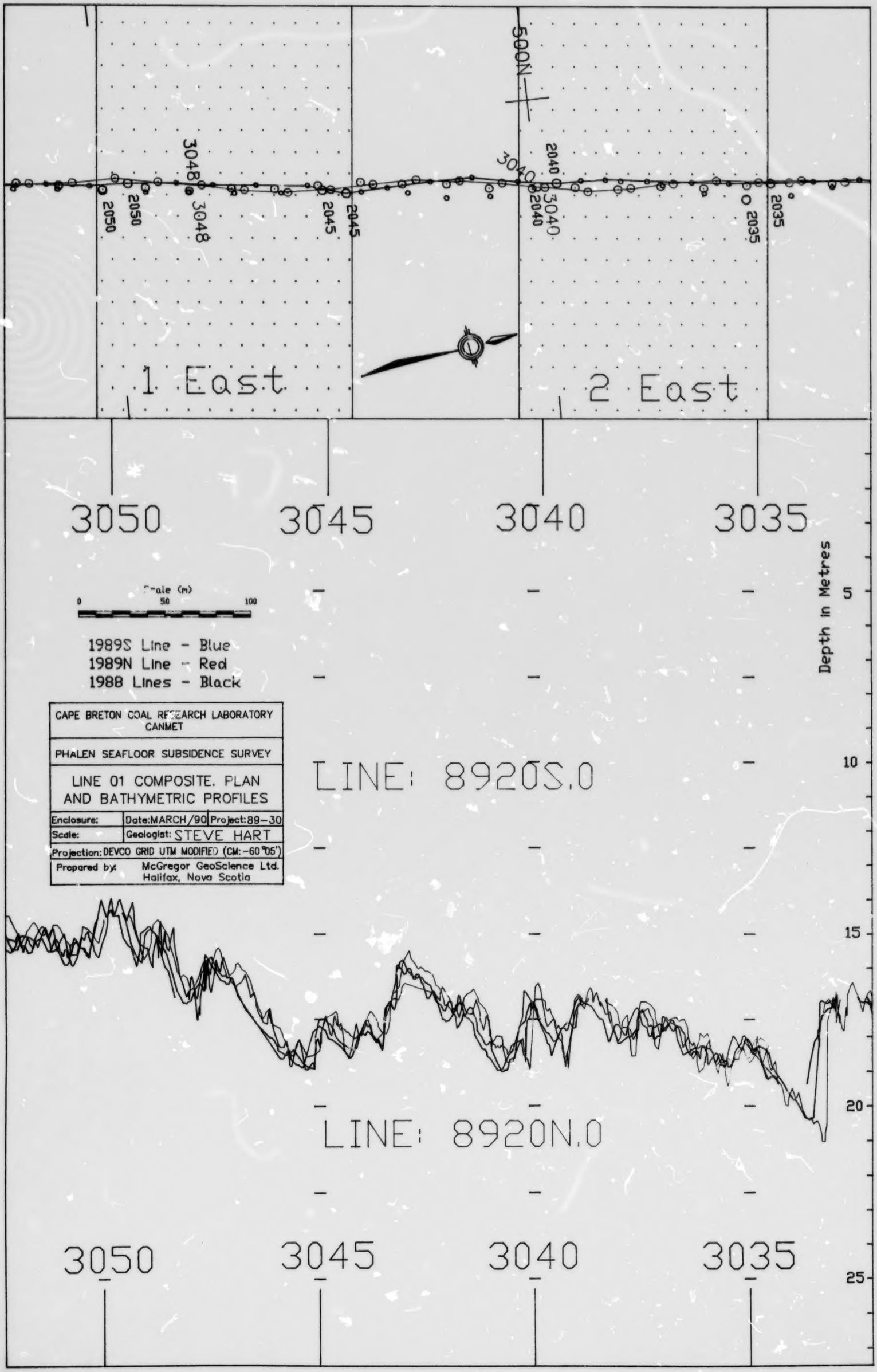
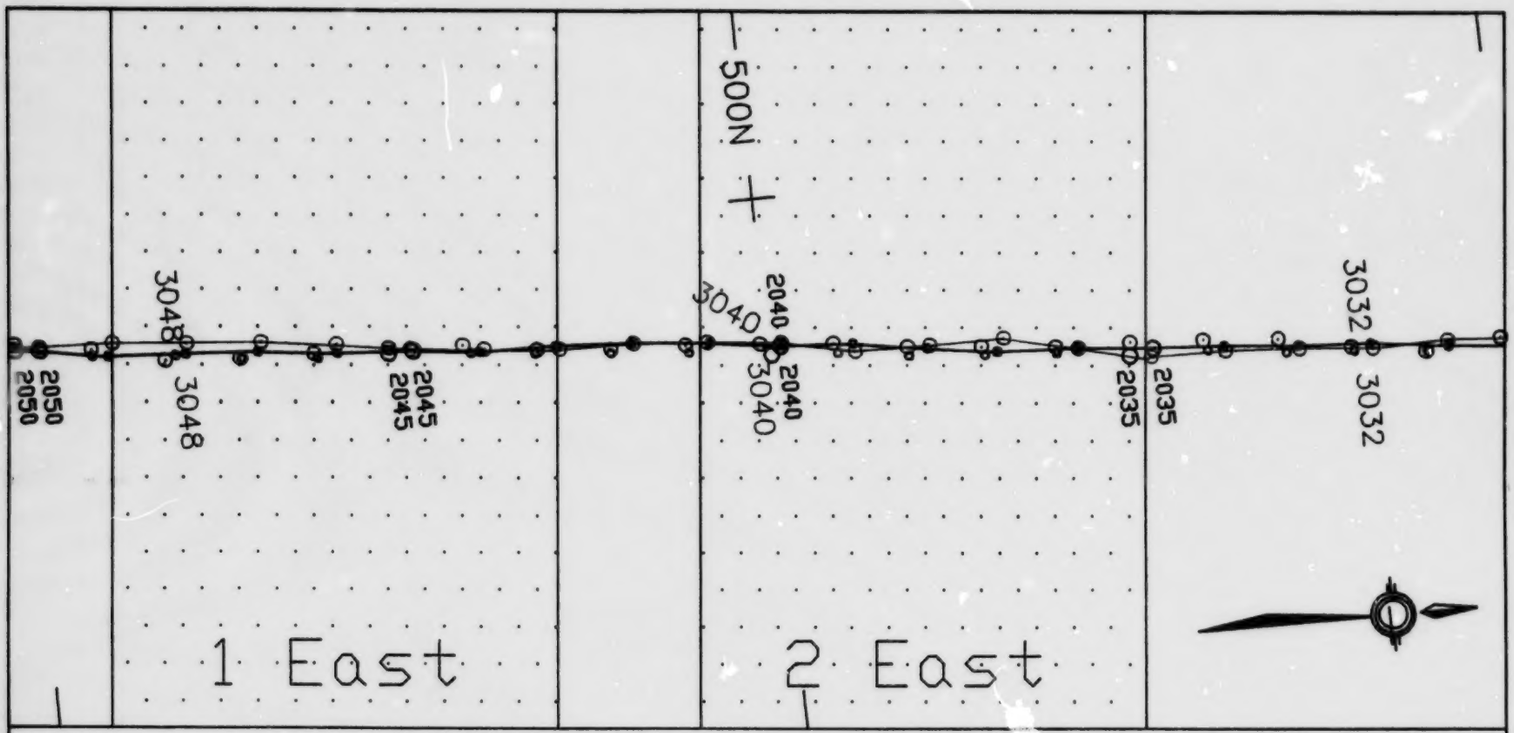
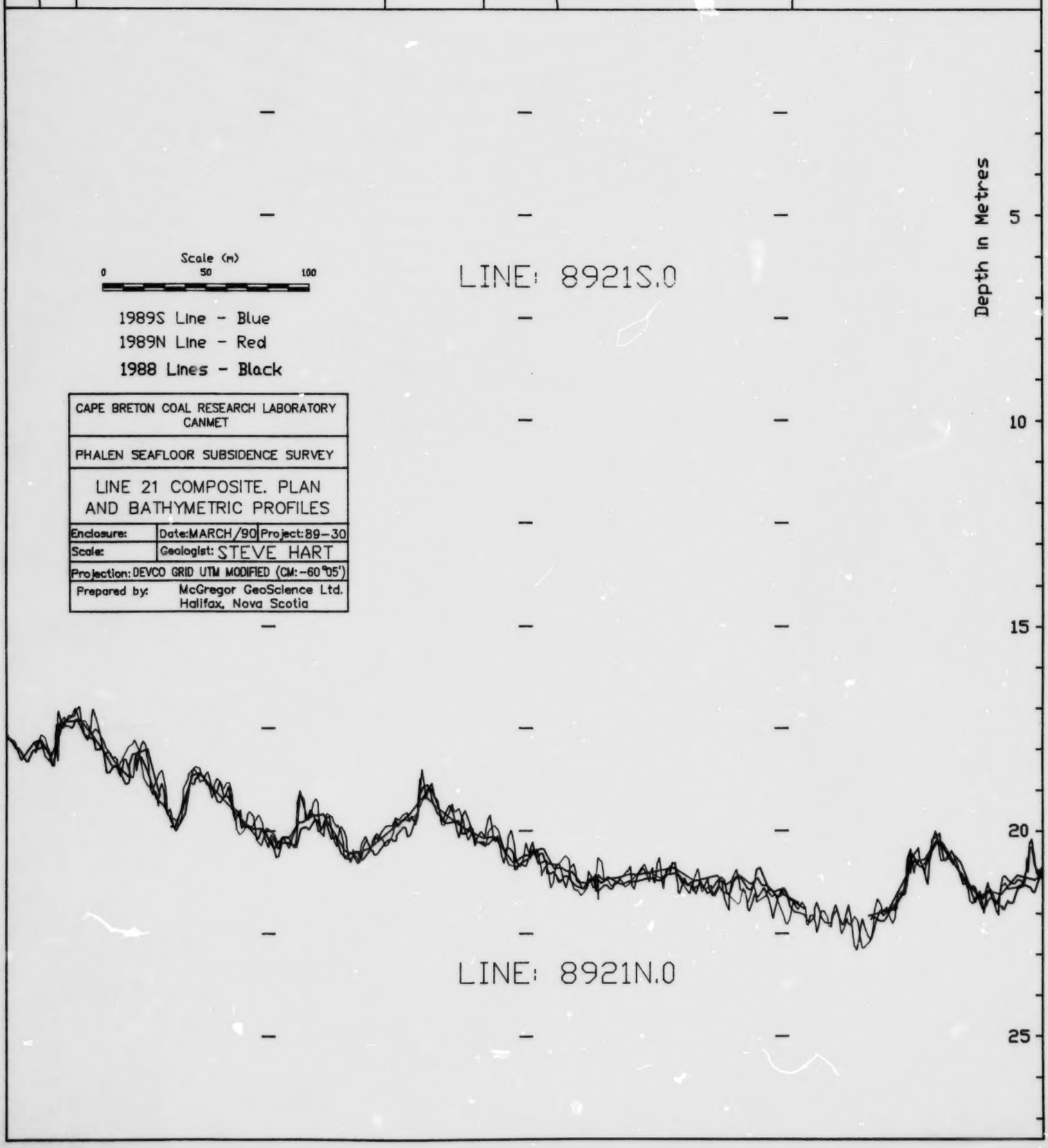

500N
3048
2050
2050
2045
2045
3040
2040
2040
2035
2035
1 East
2 East
3050
3045
3040
3035
Depth in Metres
5
10
15
20
25
Scale (m)
0
50
100
1989S Line - Blue
1989N Line - Red
1988 Lines - Black
CAPE BRETON COAL RESEARCH LABORATORY
CANMET
PHALEN SEAFLOOR SUBSIDENCE SURVEY
LINE 01 COMPOSITE. PLAN
AND BATHYMETRIC PROFILES
Enclosure:
Date:MARCH/90
Project:89-30
Scale:
Geologist: STEVE HART
Projection: DEVCO GRID UTM MODIFIED (CM: -60°05')
Prepared by: McGregor GeoScience Ltd.
Halifax, Nova Scotia
LINE: 8920S.0
LINE: 8920N.0
3050
3045
3040
3035

FIGURE 47





CAPE BRETON COAL RESEARCH LABORATORY CANMET		
PHALEN SEAFLOOR SUBSIDENCE SURVEY		
LINE 21 COMPOSITE. PLAN AND BATHYMETRIC PROFILES		
Enclosure:	Date: MARCH/90	Project: 89-30
Scale:	Geologist: STEVE HART	
Projection: DEVCO GRID UTM MODIFIED (CM: -60°05')		
Prepared by:	McGregor GeoScience Ltd. Halifax, Nova Scotia	

FIGURE 48

SECTION 3

OBSERVATIONS AND RESULTS

Section 3.1 Data Quality and Weather Conditions

Poor weather conditions frequently interrupted the 1989 field operations. This did not preclude the acquisition of the quality of data necessary for this study as the weather improved dramatically during the last day of the program. The majority of lines used in this report were collected during this good weather day. Profiles collected during separate traverses over the same survey line demonstrate very good bathymetric correlation (Figures 5 to 21). The major, and many of the minor topographic features, are easily identifiable on both profiles demonstrating survey repeatability.

Section 3.2 Areas of Possible Subsidence

The longwall geometry of the East and West Phalen mine workings at the time of 1989 survey is displayed in Figure 4. Superimposed upon this are the intended track lines as defined by the start and end fix for each line. The track lines, beneath which longwall excavation occurred after the 1987 and prior to the 1988 surveys, are documented in Table 2. These lines represent areas which may demonstrate subsidence between the 1987 and 1988 surveys. Further subsidence may also be displayed by comparing the 1988 to 1989 profiles.

Table 2

Track Lines Intersecting Longwalls Mined between the 1987 and 1988 Surveys

Longwall	Track Lines
Phalen No. 1 East	13
	14
Phalen No. 1 West	6
	5
	4
	3

Table 3 defines areas where longwall excavation occurred after the 1988 survey, but prior to the 1989 survey. The potential for observing formerly undefined subsidence exist in these new areas.

Table 3

Track Lines Intersecting Longwalls Mined between the 1988 and 1989 Surveys

Longwall	Track Lines
Phalen No. 1 East	15
	16
Phalen No. 2 East	13
	19
	20
	21
Phalen No. 1 West	1
	2

Lines which traverse unmined longwalls provide pre-mining profiles which may be used as future references for subsidence studies.

Section 3.3 Observed Subsidence

Expanded profiles (Figures 22 to 48) are provided in this report to allow direct comparison of the 1987, 1988 and 1989 survey results.

Table 4 provides the longwall mineface position within a one week window bracketing each survey line. This data is based on weekly mine face positions provided by Devco personnel.

Table 4

Mine Face Positions Bracketing Survey Lines

Colliery Name	Survey Line #	Start Week	End Week	
East Phalen No. 1	21	19/10/87	21/10/87	
	20	14/12/87	14/12/87	
	19	25/01/88	01/02/88	
	13	15/02/88	22/02/88	
	18	11/04/88	18/04/88	
	17	30/05/88	06/05/88	
	14	04/07/88	04/07/88	
	16	29/08/88	06/09/88	
	15	10/10/88	10/10/88	
East Phalen No. 2	21	29/05/89	05/06/89	
	20	26/06/89	03/07/89	
	19	14/08/89	21/08/89	
	13	28/08/89	05/09/89	
West Phalen No. 1	8	15/05/87	15/05/87	not over mined area
	7	10/08/87	17/08/87	
	6	05/10/87	12/10/87	
	5	11/01/88	18/01/88	
	4	11/04/88	18/04/88	
	3	11/07/88	18/07/88	
	2	24/10/88	31/10/88	
	1	09/01/89	16/01/89	

Outlined in Table 5 are the total observed subsidence displacements determined from the existing composite profiles. The relative time

(weeks) which has passed between the mine face intersection with the respective survey lines are also presented.

Table 5

Summary of Observed Subsidence

Colliery Name and Longwall Number	Survey Line Name	Total Observed Subsidence (metres)	Time Expired between Mining and Post-Mining Survey (weeks) 1987	1988	1989
West Phalen No. 1	8	0.0	15	N/A	N/A
	7	0.3	2	53	109
	6	0.5	N/A	44	100
	5	0.8	N/A	30	86
	4	~1.0	N/A	17	73
	3	0.2-0.3	N/A	5	61
	2	0.2-0.3	N/A	N/A	45
	1	0.0	N/A	N/A	35
East Phalen No. 1	21 *	0.0	N/A	42	98
	20 *	0.0	N/A	35	91
	19 *	0.0	N/A	28	84
	13	?	N/A	25	81
	18 *	0.0	N/A	18	74
	17 *	0.0	N/A	11	67
	14	~0.8	N/A	6	62
	16 *	~0.5-0.6	N/A	N/A	54
	15 *	~0.7-0.8	N/A	N/A	48
East Phalen No. 2	21	0.0	N/A	N/A	15
	20	0.0	N/A	N/A	10
	19	0.0	N/A	N/A	4
	13	0.0	N/A	N/A	1
	18	0.0	N/A	N/A	N/A
	17	0.0	N/A	N/A	N/A
	14	0.0	N/A	N/A	N/A
	16	0.0	N/A	N/A	N/A
	15	0.0	N/A	N/A	N/A

* - No 1987 lines available for comparisons.

N/A - Longwall not excavated beneath line prior to survey.

Section 3.4 Results

The following text provides a discussion of the observed subsidence and is organized according to colliery and longwall number.

Section 3.4.1 West Phalen, Longwall No. 1

Two profiles from the 1989 survey over the West Phalen No. 1 longwall were found to exhibit previously unidentified subsidence.

Analyses of the 1988/1989 composite profiles along line 2 (Figure 33) and line 3 (Figure 34) exhibit moderate profile divergence, with the 1989 bathymetry depressed in the immediate vicinity of the No. 1 West longwall. This subsidence is in the order of 0.2 to 0.3 metres for line 2 and 0.2 to 0.3 metres for line 3.

Longwall extraction beneath line 1 failed to produce detectable subsidence as of the 1989 survey. This may result from an insufficient amount of time between longwall excavation and surveying. Additional structural support provided by the longwall end face may also be a factor in impeding the subsidence processes in this area.

Profiles along lines 4 through 7 defined subsidence in the 1988 survey (McGregor, 1989). The 1989 survey failed to provide evidence of additional subsidence along these lines. Further subsidence may be developing at a reduced rate which is undetectable over short time periods (i.e. 1 year).

The profile along line 8 failed to demonstrate subsidence on both the 1987/1989 and 1988/1989 composite profiles. This may be attributed to the lack of a pre-mining reference profile along line 8. In addition this line is approximately 25 metres beyond the east end of the West

Phalen No. 1 longwall. Any subsidence effects along line 8 resulting from excavation of the No. 1 longwall would be reduced due to wall rock support.

Section 3.4.2 East Phalen, Longwall No. 1

The 1988 survey resulted in the acquisition of 9 north-south trending survey lines over the East Phalen No. 1 longwall. Of these 9 lines, 7 overlay longwall positions where no 1987 base line profiles existed. These lines, which include 17, 18, 19, 20 and 21, represent areas where no subsidence is observed on the 1988/1989 composite profiles (Figures 32 to 48). This is explained by the fact that longwall extraction occurred prior to the 1988 survey. Therefore, the 1988 survey is a post-mining seafloor reference profile. The failure of the 1988/1989 composite profiles to yield subsidence is attributed to the fact that the majority of subsidence occurred prior to the 1988 survey.

Conversely, lines 15 and 16 were acquired prior to longwall extraction and represent pre-mining seafloor reference profiles. The 1988/1989 composite profiles along these lines exhibit 0.5 to 0.6 metres of subsidence along line 16 and 0.7 to 0.8 metres of subsidence along line 15.

Line 13 failed to indicate subsidence on the 1987/1988 composite profiles (McGregor, 1989). This is probably a direct result of the poor quality of the 1987 base profile. The 1988/1989 composite profile along line 13 show no detectable subsidence.

The profile along line 14 defined subsidence (0.8 metres) between the 1987/1988 surveys (McGregor 1989), but failed to show convincing evidence of additional subsidence on the 1988/1989 composite profile. The absence of subsidence is attributed to a decrease in the subsidence rate, resulting in seafloor displacement too small to be resolved.

Section 3.4.3 East Phalen, Longwall No. 2

There is presently no evidence of subsidence along any of the East Phalen No. 2 longwall survey profiles. This likely results from an insufficient passage of time between mining and the 1989 survey to allow for subsidence to be initiated.

Section 3.5 R.O.V. Survey

The R.O.V. survey proved successful in visually confirming the seafloor topography implied by the echosounder records as well as confirming the absence of significant sediment accumulations.

The following observations were made from the video imagery. Although widespread kelp growth obstructs a clear view of the seafloor, exposed bedrock ledges and dipping bedrock surfaces are occasionally visible. Subangular to subrounded cobbles and boulders occur on the seafloor. However, no significant sediment accumulations or evidence of sediment mobilization was observed.

The location of the R.O.V. within the Devco grid was referenced to the survey vessel by visual reckoning of buoys attached to the R.O.V. umbilical. This did not provide the precision necessary for matching

seafloor features observed on the video with the exact topographic features displayed on the bathymetric profiles.

SECTION 4

CONCLUSIONS AND RECOMMENDATIONS

This study has proven that pre- and post-mining high resolution echosounder surveys are an effective means of monitoring subsidence in the marine environment.

The current study approach has been to acquire a discrete number of repeat transects over the Phalen Colliery. This technique has proved very successful in identifying areas of subsidence and in measuring the magnitude of subsidence.

There are some limitations to the current report. The data are presented in absolute terms without mention of confidence intervals. The author presents the subsidence measurements of Table 5 after careful consideration of the profile geometry and data quality. The values stated in this Table are conservative and are considered to be accurate.

If increased accuracy is required for tensile strain calculations, then two possible routes can be pursued.

First, the current data can be further processed with the intension of better quantifying the confidence of the reported subsidence. Most of the track lines have been repeated in the field during each survey year. These line pairs could be trace summed and averaged to produce a theoretical ideal line. The depths along this ideal line would have to be weighted to compensate for the horizontal displacement between the field track line and the theoretical track line. Ideal lines from consecutive surveys could be superimposed and differential curves

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calculated. This scientific approach would result in subsidence curves rather than the single subsidence maximums cited in Table 5.

Further data processing will quantify the width and shape of the subsidence profile, but is will probably not result in significant changes in the subsidence maximums reported in this study.

If the end users of this subsidence data require quantification in the order of 10 centimetres then there is only one route to follow.

This study has succeeded in proving without reasonable doubt in the mind of the author, that subsidence is occurring at the seafloor over the Phalen Colliery and that this subsidence can be measured using echosounder data.

To further utilize this successful technique the author recommends that a very small area (400 m x 700 m) of the Number 3 East or West Phalen longwalls be surveyed with a tight grid of short lines (5 m line spacing, 400 m line length). This extremely dense sampling of the seafloor topography would provide a 3 dimension representation of an unmined area. Because of the continuous coverage in this area there would be no ambiguity produced by line offset. Resurveying this area within a year after mining, with the same density of topographic sampling points, would provide a similar 3 dimensional representation.

The differential of these 3 dimensional grids would provide a true representation of the subsidence effect. This field of subsidence data would be infinitely superior to the single profile data which currently exists.

This is not to suggest that the technique to date is useless. The current approach should be regarded as a regional study which succeeded

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in proving subsidence is occurring at the seafloor. However if exacting measurements in the order of centimetres are required by the end users, then it is probably time to use this powerful tool to its full potential.

REFERENCES

McGregor GeoScience Limited. 1989: Seafloor Topography over the Phalen Colliery, Phase 2, Sydney Coalfield, Cape Breton, Nova Scotia, June 1985, Submitted to Cape Breton Coal Research Laboratory, Project 88-07.

APPENDIX 1

OPERATIONS LOG

APPENDIX 1

OPERATIONS LOG

The 1989 survey was conducted in two segments. Phase 1 was carried out during the period of September 5 to 10, 1989, with survey suspension resulting from storm related activity. The survey reconvened and was completed during the second phase which lasted from September 13 to 17, 1989.

Phase 1

Time (Local)	
	September 5, 1989
1800	McGregor and Nortech personnel depart Halifax for Sydney.
2330	Personnel arrive Sydney.
	September 6, 1989
0900	Arrive Great Bras d'Or, mobilization of navigational and hydrographic equipment aboard M/V IDLE OARS II commences. All but one onshore control station put in place by personnel onshore of the survey site (New Waterford). Access to one control station denied since it is no longer Devco property.
2000	UHF Trisponder calibration attempted. Aborted due to low batteries.
	September 7, 1989
0530	Vessel sailed to Government wharf, South Bar, Sydney Harbour.
0800	Survey team arrive at South Bar and divides into 2 groups, allowing one group to search for an additional onshore control station site and to carry out trisponder calibrations. The other group remain at south bar to complete mobilization.
	September 8, 1989
0800	Arrive South Bar. Onshore navigation personnel depart for transponder station.
0830	Vessel departs South Bar. Navigation problem within Devco grid recognized.

1000	On site. All four onshore control stations operating. Navigation problem corrected by Nortech personnel. 33 kHz transducer not operating.
1245	Bar check completed (1510 m/s water velocity). Transducer draft measured to be 40 cm.
1305	Commence submersible remotely operated vehicle (R.O.V.) Survey. See summary of R.O.V. Survey lines, Navigation Report, Appendix 4.
1840	Recover R.O.V. Prepare for acquisition of bathymetric lin. See summary of Bathymetric survey lines in Navigation Report, Appendix 4.
1950	Gear secured. Depart site for South Bar.
2100	Arrive at Wharf South Bar.

September 9, 1989

0800	Arrive onboard vessel.
0830	Depart South Bar.
0940	On Site. Navigational display problem recognized. Waiting for correction of navigation problem.
1020	Bar check completed (1510 m/s water velocity).
1105	Navigation receiving 3 onshore stations only, fourth is intermittent.
1310	Commence R.O.V. survey. Water appears cloudy due to wave action. See summary of R.O.V. Survey lines, Navigation Report, Appendix 4.
1840	R.O.V. onboard. Depart Site.
1945	Arrive South Bar.

September 10, 1989

0800	Arrive Vessel. Weather conditions and forecast dictate survey suspension.
1000	Partial demobilization involving collection of onshore control stations and dismantling echosounder infrastructure.
1215	Vessel departs South Bar for Great Bras d'Or.
1430	Meet Vessel at Great Bras d'Or.
1500	Depart Great Bras d'Or for Halifax.
2030	Arrive Halifax.
	Phase 1 complete.

Phase 2

September 13, 1989

1230	Depart Halifax for Sydney.
1930	Arrive Sydney.

September 14, 1989

0530	M/V IDLE OARS II departs Great Bras d'Or for South Bar.
0600	Onshore of survey area the navigation crew begin deployment of shore stations.
0720	Vessel arrives at South Bar.
0815	Arrive at South Bar and commence remobilization.
0900	Depart South Bar for Site.
1014	Arrive at Site. Commence bar check (1503 m/s water velocity). Transducer draft 40 cm. Waiting on navigational difficulties.
1148	Commence bathymetric survey. See summary of Bathymetric survey lines in Navigation Report, Appendix 4.
1544	Survey suspended for day resulting from weather, navigation and heave conditions.
1600	Bar check commenced under poor conditions (velocity 1500 to 1506 m/s).
1614	Equipment secured, depart site.
1725	Bar check off South Bar reveals water velocity of 1494 m/s.
1733	Arrive at South Bar.

September 15, 1989

0710	Arrive at South Bar.
0805	Depart South Bar wharf.
0906	Arrive site area.
0915	Transducer depth remeasured and determined to be 49cm. Complete bar check (1494 m/s water velocity).
0949	Commence bathymetric survey. See summary of Bathymetric survey lines in Navigation Report, Appendix 4.
1339	Survey suspended for day due to weather. Depart Site.
1421	Bar bheck complete inside harbour. Water velocity range of 1489 m/s to 1493 m/s calculated.
1446	Arrive South Bar wharf. Finished for day.

September 16, 1989

0750	Arrive at South Bar wharf.
0803	Depart South Bar wharf
0902	On site.
0936	Bar check completed (1494 m/s water velocity).

0947	Commence Bathymetric Survey. See summary of Bathymetric survey lines in Navigation Report, Appendix 4.
2112	Survey completed.
2123	Bar check (1490 - 1494 m/s @ 15m, 1486-1488 m/s @ 10m). Depart site.
2230	Arrive South Bar wharf. Commence partial demobilization.

September 17, 1989

Complete demobilization and return to Halifax.

APPENDIX 2

EQUIPMENT SUMMARY

APPENDIX 2

EQUIPMENT SUMMARY

During the September 1989 survey high resolution echo sounder data and R.O.V. (Remotely Operated Vehicle) seafloor video images were acquired along a previously established grid. Navigation was achieved using a trisponder microwave system. A description of the equipment employed in the Sydney geophysical survey is provided below.

Navigational Control

Primary survey vessel positioning was achieved using a Del Norte Microwave Trisponder Navigation System, Model 540, employing four onshore transponder control stations. Navigational system configuration, specification and control stations for the 1989 survey are provided in the Navigation Report (Appendix 4).

Echosounder

The high resolution bathymetric data was acquired using a Krupp Atlas, DESO-20 echosounding system, side mounted on the survey vessel, with the transducer face located approximately 0.5 metres below the sea surface. The proximity of the transponder to the navigational antenna was negligible, fixed at 0.82 metres horizontal distance. Water velocity calibrations were conducted on a daily basis, both pre-survey and post-survey to establish and confirm water velocities, these data are recorded in the Operations Log (Appendix 1).

The DESO-20 recorder allows a depth 'window' to be selected for recording bathymetric data. The window size (upper to lower recording depth range) and phase (location of the window in the water column) can be selected to maximize the resolution of the data being recorded. For the purposes of this survey, the window was set for maximum resolution, 5 metres, with the window location (phase) adjusted along the track line to compensate for gradual bathymetric changes greater than 5 metres. The phase number is annotated at regular intervals along the record and is immediately updated to record phase changes. The records are also automatically annotated as specific fix positions when these predefined locations are reached along line. Phase and depth ranges for a 5 metre window are recorded in Table 2-1.

Table 2-1

Phase and Depth Range for a 5 m Window

Phase	Depth Range
00	0.0 - 5.0 m
01	2.5 - 7.5 m
02	5.0 - 10.0 m
03	7.5 - 12.5 m
04	10.0 - 15.0 m
05	12.5 - 17.5 m
06	15.0 - 20.0 m
07	17.5 - 22.5 m
08	20.0 - 25.0 m
09	22.5 - 27.5 m

ATLAS DESO-20 Technical Specifications:

- Simultaneous, dual frequency operation: 210 kHz and 33 kHz. The 33 kHz component was not operated on the survey due to technical difficulties with the 33 kHz transducer. This had no adverse effect on the quality of the high resolution 210 kHz component.

- Digitization of water depth with LED display and output to navigation computer for permanent recording.

- Choice of vertical recording ranges permitting a wide range of vertical scales to optimize resolution.

- Recording paper speeds adjustable in 10 steps from 12.0 to .015mm/second allowing selection of horizontal scale to optimize resolution.

- Automatic annotation of recording parameters including: speed of sound in water as determined by the bar check, measuring range and phase, time and fix event mark.

- Graphical precision at 210 kHz is +/- 0.12% of depth +/- 1.5 cm, using a narrow beam transducer (9 degrees).

The echsounder was calibrated to compensate for the draft of the transducer which was determined to be 0.40 metres during the first phase of the survey and 0.49 metres for the second phase.

The speed of sound in sea water was determined using the standard hydrographic bar checking technique.

Phantom HD2 R.O.V.

An addition to the 1989 survey not present in previous years was the use of an R.O.V. submersible. This R.O.V. was used to acquire colour VHS tapes of the seafloor over the Phalen Colliery confirming the complex microtopography observed on the bathymetric profiles.

Phantom HD2 R.O.V. Technical Specifications:

Depth Rating:	305 metres. Test Depth 457 metres.
Dimensions:	1.35m L x 0.64m H x 0.56m W
Vehicle Weight:	60 kg.
Cable Length:	168 metres or 458 metres.
Cable Diameter	1.8 cm.
Cable Weight in Water:	Slightly Positive
Camera:	Color CCd, 4.8mm Fixed focus, Auto Iris lens. Full size interchangable Camera mount. Built in video switch.
Camera Tilt:	Powered by DOE Linear Drive Actuator.
Lateral Thruster:	Integrated mount built into hull.
Navigation:	Fluid-gimbaled flux gate compass. Depth transducer. Backlit LCD digital readout. Auto Depth. Auto heading. Instrument output port for optional on-screen display computer.
Controls:	Two-axis joysticks. Depth Trim. Lights. Focus. Power on/off. Video switch for second camera. Tilt/Manipulator control. Auto/Normal Depth. Auto/Normal Heading. Internal/External switch for optional remote joysticks.
Lights:	2 x 250 watts tungsten-halogen with 3 position dimmer switch.
Audio Contact Sensor:	Provides audio feedback reflecting vehicle condition.
Performance:	Forward Thrust: 25 kg. normal 36 kg. boost
Maximum Speed:	3 Kts.
Power Requirements:	120/240 VAC, 50/60 Hz, 4KVA. (Can be powered from portable 5KVA generator).
System Shipping Weight:	c/w/ 168 metre Umbilical = 295 kg. c/w/ 457 metre Umbilical = 409 kg.

Survey Vessel

The survey was conducted out of South Bar aboard a local Cape Islander style fishing vessel, the Idle Oars II.

TABLE 2-2

CONFIGURATION OF SURVEY EQUIPMENT

Navigation Antenna to vessel centre Line	-------	1.75 m
Navigation Antenna to Vessel Side	-------	0.38 m
Navigation Antenna to Vessel Stern	-------	5.64 m
Echosounder Astern of Navigation Antenna	-------	0.73 m
Echosounder to Vessel Centre Line	-------	2.13 m
Echosounder to Vessel Side	-------	0.00 m

TABLE 2-3

HOURLY WATER LEVELS AND DAILY MEANS
NORTH SYDNEY TIDAL STATION SEPT. 13, 14, 16

Time AST	Aug 8 Water Level (cm)	Aug 14 Water Level (cm)	Aug 15 Water Level (cm)	Aug 16 Water Level (cm)
0100	107	45	21	30
0200	101	56	28	18
0300	93	62	43	16
0400	73	96	67	50
0500	62	101	89	50
0600	53	130	116	101
0700	42	127	133	105
0800	48	116	140	133
0900	53	105	130	130
1000	61	72	111	116
1100	75	51	81	94
1200	80	27	59	70
1300	88	8	31	33
1400	83	21	40	20
1500	82	13	25	11
1600	76	60	66	26
1700	65	58	81	52
1800	63	103	112	64
1900	58	101	128	109
2000	67	112	144	122
2100	71	97	123	134
2200	87	83	119	123
2300	87	50	80	103
2400	105	38	47	65
Mean Height	74	72	84	74

Tidal data provided by Marine Environmental Data Services, Ottawa.

Water levels are referenced to Canadian Hydrographic Services Chart Datum 4266.

APPENDIX 3

PERSONNEL

APPENDIX 3

PERSONNEL

Field Personnel

McGregor Geoscience Limited acted as prime contractors for the 1989 survey. Direct contractual obligations included overall quality control during the field survey, collection of bathymetric data and post survey compilation, processing and interpretation of the acquired data.

John Stewart	Party Chief (Phase 1)
Jerry Munroe	Party Chief (Phase 2)
Steve Hart	Analogue Operator/Geolosist
Richard Hunter	Navigator
Jeff Wright	Navigator
Brian Eccles	Onshore Support
Brian Pyke	Onshore Support
Richard Chitteburg	Senior R.O.V. Operator
George Leroy	R.O.V. Operator
Stuart Squires	Master
Dave Oake	Mate

Interpretation Personnel

Processing, interpretation and final report were completed by McGregor personnel.

Tony LaPierre	Project Manager/Report Editor
Steve Hart	Geologist/Report Author
Robert Bekkers	Geologist/Digitization Technician
Tina Murphy	Autocad and Digitization Technician
Hilary Chisholm	Secretarial

APPENDIX 4

NAVIGATION REPORT

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1. INTRODUCTION

The Phalen Mines Subsidence Study in Cape Breton, Nova Scotia is performed by McGregor GeoScience Limited of Halifax, Nova Scotia. Nortech Atlantic Limited of Dartmouth, Nova Scotia, was contracted to provide the navigation and positioning services for the 1989 survey. The project included a bathymetric and ROV survey.

The survey was performed in September, 1989. The weather and sea conditions played a large part in the survey. A hurricane situated to the east of the survey site produced conditions that caused the shut down of the survey at one point. The survey was carried out in two parts, September 5-10 and 13-17. The sea state also affected the quality of the data collected.

Some problems were encountered with the navigation system, these were addressed and corrected. The navigation and positioning requirements were met.

This report details the survey services performed.

2. RESOURCES

The survey was performed using a Del Norte Technology UHF (Ultra High Frequency) Trisponder system interfaced with an HP computer based navigation and positioning package.

The UHF Trisponder master configuration, deployed on the vessel, consisted of a Digital Distance Measuring Unit (DDMU) model 545, a master transponder unit model 435A and an omni antenna with cabling. A complete spare system was provided. Each shore station consisted of a remote transponder model 435A and a directional antenna with cabling. Power for the shore and vessel configurations was provided by two 12 VDC batteries.

The computer system consisted of an HP 9836 computer with an Epsom printer and remote video monitor. The software applies the range data from the Trisponder in a least squares adjustment to compute the vessel's position. This position is related to line data to provide the information to enable the navigation of the vessel along a predetermined line. This information is presented on the remote video monitor for the helmsman.

Events are generated at preselected intervals along the line, based on either time or along line distance travelled. At the event, a trigger is sent to the sounder to mark the sounding roll and the position and raw data is stored to disc and printed. The data stored to disc is used for the post-processing and plotting.

The range accuracy of the Trisponder is 1-2 metres, the position accuracy is +/- 3 metres.

3. FIELD SURVEY

3.1 Coordinate System

This survey was performed employing a local grid system, the CBDC grid. The origin of the grid is at the following point :

Latitude : N 46 14' 59.05"
Longitude : W 60 05' 00.47"

The grid is tied to and employs the same parameters as the Nova Scotia geodetic network. For further information concerning this grid the CBDC survey staff can be contacted.

3.2 Shore Stations

The shore stations used for this survey were located along the coast and chosen to provide coverage of the survey site from all four stations with the strongest geometry possible. The location of the two sites and the shape of the coastline made this difficult resulting in parts of the survey area being covered by only three stations. The coordinates of the shore stations used are given in Table 1. Shore Station Coordinates.

Table 1. Shore Station Coordinates

Station	CBDC Grid Coordinates Northing	Easting	Antenna MSL Elev
Low Point Lighthouse L.R.I.S. #1576	1 956.8	-3 362.0	12.0
New Waterford L.R.I.S. #1614	464.2	207.0	18.0
Lingan Airshaft	- 8.6	2 314.6	21.0
Timmons Point L.R.I.S. #19728	-3 273.4	6 083.1	20.0

3.3 Calibration of the Trisponder

The Trisponder is calibrated over a known baseline to determine the internal delays and the delays in the antenna cable. The sum total of these delays is the calibration value. A calibration value is determined for each shore station.

The system was calibrated over the baseline between the following stations :

L.R.I.S. #1177	N 5 125 086.858 E 727 610.661	ATS 77
L.R.I.S. #19728	N 5 122 664.921 E 731 018.333	UTM Coordinates

The geographic baseline length is 4 180.5 metres.

The calibration values were input directly to the DDMU.

The system was calibrated September 7 and used for the period of September 7-10. Upon return to the site, the same calibration values were used for September 14. Sea conditions caused the survey to be halted early this day so the system and the spare were re-calibrated in the evening. A change was found in the values but a check on the surveying performed this day implementing the new values showed the adjustment to be negligible. The data for September 14 was not therefore re-processed. The spare system with calibration values was used for the remainder of the survey and a post-survey calibration check confirmed them.

3.4 Survey Sites

The survey covered two sites, West Phalen and East Phalen. The coordinates of the the survey lines are given in Table 2. Line Coordinates.

Table 2. Line Coordinates

Line Name	Start of Line Northing	Start of Line Easting	End of Line Northing	End of Line Easting	Length
West Phalen					
8901	2100.0	1600.0	887.3	1296.8	1250.0
8902	2000.0	1800.0	890.5	1497.4	1150.0
8903	2000.0	2000.0	890.5	1697.4	1150.0
8904	2000.0	2200.0	793.5	1873.2	1250.0
8905	1900.0	2375.0	790.5	2072.4	1150.0
8906	1800.0	2540.0	690.5	2237.4	1150.0
8907	1800.0	2740.0	690.5	2437.4	1150.0
8908	1800.0	2940.0	592.2	2617.9	1250.0
8909	1280.0	1100.0	800.0	2920.0	1882.2
8910	1500.0	1100.0	970.0	3100.0	2069.0
8911	1700.0	1175.0	1173.4	3156.2	2050.0
8912	1940.0	1150.0	1355.0	3200.0	2131.8

Table 2. Line Coordinates Cont'd

Line Name	Start of Line Northing	Start of Line Easting	End of Line Northing	End of Line Easting	Length
East Phalen					
8913	1500.0	4950.0	0.0	4800.0	1507.5
8914	1500.0	4150.0	0.0	4000.0	1507.5
8915	1500.0	3650.0	0.0	3500.0	1507.5
8916	1500.0	3900.0	0.0	3750.0	1507.5
8917	1500.0	4400.0	0.0	4250.0	1507.5
8918	1500.0	4650.0	0.0	4500.0	1507.5
8919	1500.0	5150.0	0.0	5000.0	1507.5
8920	1500.0	5400.0	0.0	5250.0	1507.5
8921	1500.0	5650.0	0.0	5500.0	1507.5
8922	445.0	3000.0	280.0	5850.0	2854.0
8923	690.0	3000.0	520.0	6000.0	3004.8

3.5 ROV Survey

The ROV survey original proposed for the ROV to maneuver along select lines. Difficulties handling the ROV resulted in a change to the process. An attempt to steer the ROV along select lines was still made, but the emphasis was placed on keeping the vehicle in the general area and direction desired and estimating it's position relative to the vessel at each event. The navigation system evented at one minute intervals. A summary of the ROV lines is given in Appendix A. Line Summaries.

3.6 Bathymetric Survey

The bathymetric survey was hindered by the sea conditions and not all lines were run. Another consequence was the seas effect on the vessel. The large swells tended to make it difficult at times to maintain a steady course and speed along the survey line, particularily in the shallows where the swell would build up. As a result the spacing on the sounding record between events does not always appear even, although the data and fix marks are correct. Events were generated at 25 m intervals along the lines.

The sounding lines were run in both directions when possible, as dictated by time and prevailing conditions.

A problem arose when running lines whose length was not a multiple of 25 m, the event interval. In these cases, the events generated running one direction are offset from the same numbered events generated running the reverse direction by the remainder when the total line length is divided by 25 m.

To explain this, the north/south line 8913, whose length is 1507.5 m, is examined. Running this line in a southerly direction with the first event, 3000, occurring at the start of line, the most northerly point, the last event, 3060, occurs at 1500 m from the start of the line but 7.5 m from the end. Running the line in a northerly direction, the start and end points are reversed. The first event, 3060, occurs at the 'new' start of line, the most southerly point, which is 7.5 m south of the previous event 3060. This offset is consistent along the line, the last event, 3000, occurring 1500 m from the 'new' start of line but 7.5 m south of the 'new' end of line, the position of the previous event 3000.

This must be noted for analysis of the sounding data.

A summary of the information describing the lines run is given in Appendix A. Line Summaries.

3.7 Problems Encountered

Three problems with the navigation and positioning system were encountered during the survey :

1. The automatic eventing occasionally failed the first few days of the survey. To continue the survey, the eventing was performed manually resulting in uneven event spacing on some of the first lines, even though the actual position data is correct. This was corrected and performed well for the majority of the survey.

2. The first DDMU failed several times. The replacement of this unit with the spare, once calibrated, corrected this.

3. The remote video display for the helmsman at first gave only the line tracking information graphically (offset). This was improved to also show the orientation of the vessel's heading with respect to the line. While this point did not impede the progress of the survey, the modification made it much easier for the helmsman to perform his task.

The use of the local CBDC grid also presented some problems. The only adequate means of obtaining the necessary survey control data was through contacting the CBDC survey staff. The effort should be made to obtain from the CBDC all information and formula required to perform any survey and computations in this area using the local grid and formally document it for future reference.

4. SUMMARY

Problems were encountered with the navigation and positioning system provided by Nortech that resulted in some down time and uneven event spacing. The problems were addressed and corrected and the final survey results met the project requirements.

The prevailing sea conditions resulted in some down time. The only effect of the conditions on the navigation and positioning was to make it difficult to maintain the vessel's course and heading at times.

The survey lines should be modified such that their lengths are an even multiple of the event spacing. This would eliminate the event position offsets when running in two directions.

The ROV survey requires a means by which to position the ROV to the accuracy that would enable proper navigation. The use of an acoustic tracking system is recommended.

A more detailed documentation on the local CBDC grid would be of great advantage for future surveys.

Summary of ROV Survey Lines

The table below, ROV Survey Lines, gives the lines attempted in the ROV survey. The last line listed, ROV8909W.0, was actually run in several segments, but for processing and plotting the segments were combined and referred to as one line.

ROV Survey Lines

Date	Line Name	Event Numbers First	Event Numbers Last	Local Time SOL	Local Time EOL
Sept. 8	ROV8901.0	3001	3032	14:07	15:06
Sept. 8	ROV8911W.0	3000	3016	18:27	18:42
Sept. 9	ROV8911W.1	3000	3033	13:50	14:14
Sept. 9	ROV8911W.2	3034	3048	14:27	14:39
Sept. 9	ROV8922W.0	3000	3044	15:20	16:04
Sept. 9	ROV8922W.1	3100	3124	16:43	17:07
Sept. 9	ROV8909W.0	3000	3053	17:24	18:34

Summary of Bathymetric Survey Lines

The table on the following pages summarizes the lines run for the bathymetric survey, including comments to assist in the analysis of the data collected. The letter in the Line Name gives the direction the line was run. The number after the decimal gives run attempt.

Bathymetric Survey Lines

Date Sept	Line Name	Events First	Events Last	Local Time Start	Local Time End	Comments
8	8911W.0	3000	3082	18:57	19:14	Manual eventing, spacing uneven but positions good.
	8901S.A	3000	3050	19:32	19:45	Manual eventing, 3022-3026 & 3029 questionable.
14	8901S.0	3000	3012	12:06	12:09	Line re-run, this data not used.
	8901S.3	3000	3031	12:21	12:29	Good, until aborted due to navigation system.
	8901S.4	3030	3050	12:47	12:51	Good, misclosure @ 3042 6.8m late, 3046 15.8m late, 3047-3050 spacing may appear uneven due to excessive vessel movement in swell build-up in shallows.
	8902S.0	3000	3046	13:12	13:20	Good, misclosure @ 3038 4.6m late, 3041-3046 spacing may appear uneven due to excessive vessel movement in shallows.

	8903N.0	3046	3000	13:34	13:44	O.K. spacing may appear uneven at beginning of line due to swell build-up in shallows. Misclosures @ 3039 5.4m late, 3008 9.3m late.
	8904S.0	3000	3050	13:53	14:03	O.K., misclosures @ 3043 8.2m late, 3036 4.9m late & 3048 7.0m late. Spacing may appear uneven last 150m due to swell build-up in shallow water.
	8905N.0	3046	3000	14:15	14:25	Pitching of vessel affecting ability to navigate line, misclosures @ 3045 8.3m late, 3042 7.6m late, 3041 2.6m late & 3010 7.4m late.
	8906S.0	3000	3036	14:35	14:44	O.K. until aborted due to seas.
	8907S.0	3000	3017	15:04	15:07	O.K. until aborted due to bad events.
	8907S.1	3015	3035	15:16	15:20	O.K., navigation on two ranges, misclosures @ 3020 19.5m early (bad event), 3032 7.5m late & 3033 11.2m late. Aborted at 3035, 3032-3035 O.K.
	8908S.0	3000	3035	15:36	15:44	O.K., misclosures @ 3002 4.5m late, 3030 9.5m late & 3032 7.8m late.
15	8915S.0	3000	3060	09:56	10:08	O.K.
	8914N.0	3060	3018	10:18	10:29	O.K. but a lot of vessel movement, aborted early.
	8918S.0	3000	3060	10:41	10:59	Auto eventing 3000-3013, manual eventing 3014-3060.
	8922W.0	3114	3000	11:38	11:56	Auto eventing 3114-3033, manual eventing 3032-3000.
	8909E.0	3075	3000	12:19	12:55	Manual eventing for all but first 3 events.
	8909W.0	3000	3075	13:26	13:38	Auto eventing 3000-3028, manual eventing 3029-3075.
16	8923W.0	3000	3087	09:55	10:22	O.K. except event 3071 missed. Aborted due to loss of power to Trisponder.
	8923E.0	3120	3081	10:53	10:59	O.K., aborted at event 3080 due to bad range data.
	8923E.1	3084	3000	11:11	11:24	O.K., overlap of line 8923E.0 of 87m.
	8920W.0	3060	3000	11:48	12:02	O.K. but a lot of vessel movement due to seas.
	8921S.0	3000	3060	12:07	12:18	O.K. except misclosure @ 3053 4.7m late.
	8919W.0	3060	3000	12:44	12:58	O.K., 1m swell on bow.

8913S.0	3000	3060	13:07	13:19	O.K., 1m swell on stern.
8917N.0	3060	3000	13:30	13:44	O.K., 1-1.5m swell on bow.
8916S.0	3000	3054	13:57	14:07	O.K., aborted when sounder ran out of paper.
8918N.0	3060	3000	14:23	14:37	O.K., 1m swell on bow.
8914S.0	3000	3060	14:58	15:09	O.K., 1m swell on stern.
8908N.0	3050	3000	15:30	15:41	O.K.
8907S.2	3000	3046	15:47	15:56	O.K.,except events 3035-3039 need shifting on the sounding roll, use events 3034 & 3040 for interpolation.
8906N.0	3046	3000	16:12	16:27	O.K., except event 3045 is bad, 3044 is missed, 3038 misclosed 5.2m late and 3019 did not mark on sounder.
8915N.0	3060	3000	16:45	16:58	O.K. except misclosure @ 3043 4.3m late.
8920S.0	3000	3060	17:08	17:19	O.K. except event 3021 missed.
8921N.0	3060	3000	17:30	17:43	O.K. except event 3002 missed.
8919S.0	3000	3060	17:52	18:02	O.K. except event 3008 missed.
8913N.0	3060	3000	18:07	18:20	O.K.
8917S.0	3000	3060	18:30	18:42	O.K. except misclosure @ 3045 1.8m early.
8916N.0	3060	3000	18:54	19:07	O.K. except misclosure @ 3058 2.0m early. 1m swell out of NW.
8905N.1	3046	3000	19:25	19:34	O.K. except seas causing vessel to pitch affecting speed. Events 3043 & 3042 look questionable on sounding record, should interpolate between 3044 & 3041. 3011 not marked on sounder.
8903S.0	3000	3046	19:41	19:50	O.K. except event 3032 missed and 3033 misclosed 2.7m early.
8904N.0	3050	3000	20:01	20:12	O.K. except event 3050 is bad and due to sea conditions speed of vessel fluctuating at event 3019-3015, may need to interpolate between 3020-3014.
8905S.0	3000	3046	20:18	20:27	O.K. except event 3004 missed.
8902N.0	3046	3023	20:34	20:38	O.K. until aborted at event 3023 due to bad range data.

8902N.1	3046	3000	20:46	20:51	O.K. but swell in shallows causing vessel speed to fluctuate and therefore event spacing on sounding record to be uneven.
8901N.0	3050	3000	21:02	21:12	O.K.

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